THE SALT BATH TREATMENT OF METALS

Paper presented to the Institution, Western Section, by W. Nelson and F. D. Waterfall.

SINCE metallurgy became a science—and that is not so long ago—it has been realised that the atmosphere can be a serious detriment to certain metallurgical operations. The majority of the common metals oxidise under normal atmospheric conditions. Increase of temperature, among other things, promotes chemical activity, and the hotter you make a metal in presence of air, the more rapidly it oxidises. Much ingenuity has been exercised in endeavours to exclude the atmosphere from metals at the elevated temperatures of heat-treatment, but quite the simplest and most effective is the use of a suitable salt bath.

The measurement of temperature in the elevated ranges is another trouble in heat-treatment. Assuming the pyrometer is accurate, it is still necessary to exercise care and skill in order to arrive at the true heat of the metal under treatment. In the salt bath, the pyrometer shows the actual temperature of the job and not of the furnace, and it is only necessary to ensure that the pyrometer is maintained in working and accurate order.

Exclusion of the atmosphere from the furnace prevents scaling and waste. Correct temperature control enables maximum properties to be developed in the metal with certainty. These are the two principal advantages of the salt bath method of heat-treatment. There are many other advantages such as speed of heating and speed of carburising which will be dealt with later.

The modern range of salt bath furnaces covers practically every heat-treatment operation. There are certainly some processes, such as annealing, which may be more cheaply carried out by muffle furnaces, but hardening and tempering can generally be done both expeditiously and efficiently by means of the salt bath.

The highest temperature employed in the normal heat-treatment of steel is in the region of 1,350°C. and for this purpose a salt, whose trade name is "Carboneutral," is efficiently employed for the hardening of high speed steel. Temperatures in the neighbourhood of 1,050°C. are used for the treatment of austenitic steels and a similar salt is available for this purpose. Carburising operations are generally conducted between 950° and 850°C. and there are a number

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of cyanide-containing proprietary salts available for this purpose. The hardening of carbon and alloy steels and also case-hardened steel is done at temperatures between 850° and 760°C. although some observers recommend temperatures as low as 710°C. for this purpose ; again salts are available for this range. Also in this range certain non-ferrous operations are carried out, such as the annealing of German silver and this can also be done efficiently in salts. At lower temperatures brass and similar alloys anneal and certain alloy steels are tempered. Specially compounded salts are available for temperature range 700° to 600°C. for such purposes, and below 600° right down to 150°C. mixtures of nitrates are employed for the tempering of steel and for the heat-treatment of light alloys.

High-speed steel is used in large quantities to-day to deal with the very high production required by modern conditions and this material has always been difficult to harden. The high temperatures required promote oxidation and the old-fashioned methods produced tools which were badly scaled, in fact, originally, the hardener of high-speed steel would watch the tool in the furnace until it started to melt when he withdrew it and cooled it in whatever way was required. This is obviously a crude and unsatisfactory method. Thereafter improved furnaces were designed with artificial atmospheres which to a certain extent protected the steel from oxidation, but here again trouble arose since these atmospheres generally consisted of coal gas. If the carbon monoxide content of the furnace atmosphere was allowed to predominate, the tool would never attain the temperature indicated by the pyrometer, and would be incompletely hardened. Again, if the CO_2 or carbon dioxide content became too great, the steel actually became hotter than the temperature indicated by the pyrometer, with the consequent trouble of excessive grain growth and sometimes burning. In the case of tools with very fine edges, such as thread rolling dies, it is a not uncommon practice to harden these at comparatively low temperatures, such as 1,200°C. in order to avoid excessive scale with consequent spoilage of the profile of the tool, thus preventing the full hardness of the steel being developed, which is reflected in short life in service.

Even with the best of such furnaces a soft skin due to decarburisation was obtained, particularly in the case of steels containing cobalt, and this necessitated more or less extensive grinding after hardening, which in many cases is a very difficult and expensive operation. By treating such steel in the proper salt bath, these troubles are completely removed. The tool may be taken safely to its optimum temperature and soaked for as long as desired in order to ensure the completest possible solution of carbides and so obtain long life in service.

Austenitic, stainless steels and certain classes of tool steels are heat-treated in the region of 1,050°C. and the same type of furnace as for high-speed steel may be used but with a different salt.

Carburising is usually conducted between 850° and 950°C. The higher the temperature, the quicker the penetration. For deep cases we use a somewhat complex salt known as Rapideep. For shallow cases and for delicate work, we use ordinary sodium cyanide.

The unalloyed carbon case-hardening steels are carburised at 950°C. owing to the greater speed of penetration, and since this class of steel does not form free cementite in Rapideep.

The nickel-chromium case-hardening steels and those of more complex analysis are frequently carburised at 900°C. On account of the slow rate of diffusion of carbon into such steel it is advisable to supply the carbon slowly and thus avoid the danger of building up excess carbon, which takes the form of cementite on the surface.

Where distortion is feared, carburisation should be done at 850°C. and at even lower temperatures when handling very delicate components.

The cyanide bath and various salts containing cyanide are very suitable for heat-treating carbon and alloy steels. As mentioned earlier, the steel is protected from oxidation, scaling, and decarburisation. The rate of heating is high and the output large. A salt bath heat-treatment furnace will give an output of a muffle furnace four times its size and cost. Temperature control is absolute. The actual temperature of the job, and not of the furnace is indicated on the pyrometer. Heating is uniform.

Steel makers and engineers now appreciate that heat-treating steels are frequently improved by treatment in the cyanide bath. Gears are a case in point. There are several varieties of oil-hardening gear steels on the market such as carbon-chromium, nickel-chromium, chromium vanadium, etc. These can be hardened by simple heating and quenching, but when this treatment is carried out by the cyanide process, not only do the cleanliness, speed and accurate control keep down costs, but the slight case hardening effect of the cyanide results in greatly improved life and reduction of noise.

Salts made from nitrate-nitrite mixtures and having a working range of 150° to 600°C. are on the market. From 600° to 700°C. it is better to use chloride mixtures, since nitrates tend to attack the pot above 400°C. and particularly above 600°C.

Of recent years much has been said, in advertising literature, of the nitriding effect of the cyanide bath. It has been alleged that nitrogen penetrates and embrittles the steel. It is true that nitrogen is taken in by the steel from the cyanide bath, but this is an advantage rather than a drawback.

The hardness of a case produced in Rapideep or cyanide is neither more nor less than that obtained by good packhardening technique.

It is an inherent quality of fully hardened high carbon steel to have little resistance to failure under shock. This property may be called "brittleness," but, unfortunately, this word seems to convey a reproach. But one must not reproach such material with being brittle since this is the property we have been endeavouring to produce, and when success attends our efforts it is an occasion for rejoicing, not sorrow.

If, however, a casehardened piece breaks with a similar fracture to that of a hardened high carbon steel, it may truly be reproached with "brittleness" and the detraction of the cyanide process suggests that the nitrogen penetrates to the core, and lessens the resistance of the piece as a whole to fracture under shock.

It is known that a case of pure nitride, as is obtained by the ammonia nitriding process, is extremely hard and might justifiably be called brittle. This is shewn by spalling when a nitrided specimen is bent. The case produced in the cyanide bath is not so hard as a pure nitride case, and although it is as hard as a packhardened case, it is not so easily cracked as the latter. I will not endeavour to explain this phenomenon. It has been suggested that the cyanide case contains compounds of iron, nitrogen and carbon and that the physical properties of such compounds might vary widely from those of iron carbide and/or iron nitride.

Discussion

MR. DANIELS (Section President, in the chair): In dealing with steels, I should like to ask the lecturer to tell us about the various salts and how they are obtained for the job. I have had but small experience with them.

MR. WATERFALL: The salts used vary with the temperatures at which they are required to work. For low temperature work, as for heat treatment of light alloys and for the tempering of hardened steel, mixtures of nitrates are used and comparatively cheap mixtures of sodium and potassium nitrates are satisfactory between temperatures of 250° and 600°C. Below this range more expensive mixtures, containing nitrates are necessary, and, above, various chloride mixtures can be used. Unfortunately at higher temperatures, such as 850° to 1,000°C. the chlorides possess the property of decarburising. Carburising baths must contain cyanide in some form or other. Full strength cyanide, however, is not used, but a mixture of sodium carbonate, which is to all intents and purposes washing soda, and cyanide in equal parts by weight. The cyanide used is sodium cyanide and not potassium cyanide as formerly, since the sodium salt is stronger, cheaper, and more stable at elevated temperatures.

MR. JOHNSON: How is the temperature controlled? Mr. Nelson mentioned that the voltage varied between 8 and 20. I presume therefore that a heavy current is used. What is the approximate life of the salt? Mention was made that 300 lb. of work could be carburised to a depth of .06 in. in six hours at 950°C. As the salt becomes weaker during this period, how much salt would be required to bring up the strength? What material is used for electrodes? Copper obviously would not do. In the case of bulky jobs, do you require to leave them in longer than for the same weight of small jobs? I have in mind press tools which might be 6 in. to 8 in. in diameter.

MR. WATERFALL: There would appear to be some confusion between the types of furnaces. Two electric furnaces were shown. The first of these is to work at a temperature of 1,300° to 1,350°C., and is lined with bricks in contact with which the salt is melted. The second type is for carburising, using cyanide, and in this case the pot is of metal and the temperature does not exceed 950°C. The former type is controlled by hand and the radiation pyrometer is calibrated against an immersed thermo-couple by means of diaphragms until it gives true readings, although not working under true black body conditions. It is, of course, necessary to check it periodically with an immersed thermo-couple. The carburising

furnace is controlled automatically by means of a controlling pyrometer which works a mercury switch, which in turn operates the contactor gear and so regulates the input from the transformer. An individual job weighing X lb. would take no longer to carburise than X parts weighing 1 lb. each. Regeneration of the salt is generally done once per shift although there is no objection to introducing fresh salt with every charge, providing the carburising period extends over several hours.

MR. PERKS: Mr. Nelson mentioned the old trouble of obtaining good hardness on high speed steel cutters and that this was generally achieved by holding the steel in the furnace until it started to melt. Mr. Nelson comes from Oldbury and the next village is Smethwick, where we have people building muffle furnaces with controlled atmospheres which allow the hardener to hold the cutter at the temperature without scaling. I should like to know if Mr. Nelson was aware of this firm. I should also like to ask if he has any information about the American hardening process in which the metal is heated by induced currents, and only the journals of such components as camshafts are hardened. This process is working in the North of England and will doubtless come South.

MR. WATERFALL: With reference to the heating of high speed steel, I think one point in Mr. Nelson's lecture was overlooked, although he went into details. In the old-fashioned process the hardener watched the steel until it, or rather the scale, started to melt. The modern controlled atmosphere furnace is a distinct advance but is by no means perfect. An excess of oxygen or carbon dioxide will still produce scale and scale may thus be produced although no free oxygen is present. This causes the temperature of the tool to rise above that of the furnace since the formation of scale is an exothermic reaction. On the other hand, if the atmosphere is rich in unburned carbon monoxide then the temperature of the tool will not attain the temperature of the furnace, even though it is left in for half-an-hour. The salt bath furnace gets over all these difficulties and allows the hardener to achieve the true temperature required with a complete absence of scale. Even though no scale is evident, however, it is quite common to get a soft skin with high speed steel due to decarbonisation, but the Carboneutral salt prevents this also. We are also aware of the induction hardening process mentioned by Mr. Perks and which certainly has advantages. It is obvious, of course, that one must start with a steel which will harden by simple heating and quenching, and so it is not a true case-hardening process.

MR. DANIELS: I am rather anxious as to whether the cyanide process will come under special precautions? Surely the fumes have to be guarded against?

MR. WATERFALL: To the best of our knowledge there are no regulations against the use of cyanide for hardening purposes. Sodium cyanide is only a poison if taken internally. When it is melted in contact with air, and the surface of the salt is not protected from the atmosphere by a layer of carbonaceous matter, a white fume can be observed rising from the surface. This is substantially sodium carbonate, or a form of washing soda. Inspectors from the Home Office have taken samples of the atmosphere in various parts of our large hardening shop at Oldbury and have found no traces of cyanide fumes. The fume, however, is irritating and if the surface of the bath is kept covered with a suitable compound no fume whatever is formed.

MR. WRIGHT: In connection with high speed steel, I might mention that I am interested in some special reamers. We call for a minimum Rockwell hardness of 65-66. Only about 25% are up to that figure, and the remainder only 60 Rockwell. Now I should like to know if these reamers could be hardened in the salt bath to 65-66 Rockwell?

MR. WATERFALL: You really now ask for a discussion on an enormously wide field. The low Rockwell hardness may be due to any one of many reasons, not neglecting the steel from which the reamers are made. Also it does not follow that the reamers of the lower hardness will not be as satisfactory in service as the harder ones. It is not the hardness at atmospheric temperature which matters, but the hardness of the steel at a red heat. If we could find some means of measuring hardness of high speed steel at a red heat we would be in a better position to identify what cutters could be expected to give superior service.

MR. WRIGHT: These cutters never attain red heat. They have not attained a red heat on the cutting edge because they turn very slowly.

MR. WATERFALL: Let me put it like this. The chips which come off on cutting are very often blue, even when a coolant is used. Now whilst the whole of the chip has been heated to this temperature (300 to 350°C.) the heat has been generated between two faces involving a smaller area or volume. The faces generating the heat are obviously hotter than the material they heat. Tests have shown that these faces actually get to a dull red heat during moderately heavy working. In the salt bath process using Carboneutral, we are able to get great uniformity of temperature and to achieve the maximum temperature without danger of scaling, and so there is a better hope of achieving a uniform hardness. One must not forget, however, when unsatisfactory or non-uniform hardness is obtained that other factors besides the hardening, such as the original steel, may be influencing the matter.

MR. JOHNSON: I am not quite clear about the protection of surfaces required soft in the cyanide bath.

MR. WATERFALL: It is admittedly more difficult to protect surfaces from carburising in the cyanide bath than in the pack method. When pack hardening sufficient protection is sometimes obtained by covering certain parts with clay, but the salt removes the clay very quickly and the clay also decomposes the salt. Copper-plating, however, is an efficient method if the plating is done properly. The metal must be thoroughly cleaned before being plated and a sufficient deposit must be put on to circumvent porosity. On the other hand, it is sometimes possible to dispense entirely with protection when using the cyanide bath, since the depth of case can be controlled very accurately and there is no fear of carburising to a greater depth than is required.

THE PLANNING AND PROGRESSING OF WORK THROUGH THE SHOP

Paper presented to the Institution, Sydney (Australia) Section, by S. E. Barratt, A.M.I.P.E.

THE word "planning" when applied to works administration, especially in the metal industry, is subject to two definitions. The first would probably be the planning of all operations of production and would include jig and tool design, work processing and time study and ratefixing as its principal functions. This could therefore more briefly be stated as process planning. The second definition would be the planning of the order of production operations.

For the purpose of this paper this second definition has been used as being more in keeping with the second portion of the title and the paper is an attempt to traverse briefly the portion of factory administration that is concerned with the planning of the order of production and the steps that have to be taken to ensure that this plan can be performed.

As the means towards this end, and in the execution of its several functions of direction, co-ordination and control, modern industrial administration employs the Progress Department. It is for this reason that the progress department plays such an important part in the administration of a producing establishment, both within and without the metal industry.

The Purpose of the Progress Department.

The progress department exists in some form or other in the smallest of well managed organisations and it should exist in a clearly defined form in the largest. While its scope varies considerably, even in factories of comparable size and output, its real function never changes. Primarily a progress department exists for the purpose of ensuring that all productive activities are so arranged that, when co-ordinated in the form of assembled pieces of apparatus, the ultimate users are satisfied that the apparatus is delivered to them by the specified date.

The vagaries of the sections of the manufacturing unit and the external organisations on which it relies for its supplies of raw materials, combined very frequently with those of the customer

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himself, will therefore under such a definition make it almost impossible to create or develop a perfect Progress Department. Even were it possible to achieve perfection, commercial circumstances would generally make it imperative to be content with results still short of this desired end.

In the engineering industry, to which much of this paper applies with particular force, the Progress Department is necessary if for no other reason than to act as liaison between the selling or commercial departments and the works. Commercial or sales engineers must have reliable data on which to base delivery promises for standard equipment and such data can be provided by the Progress Department keeping those concerned fully aware of the general factory load. For special work it is necessary that the sales or estimating engineers should refer to the Progress Department for delivery dates which must frequently be given on the understanding that they are subject to revision if the order does not eventuate by a certain date. This is particularly the case where the works produces a wide variety of products and where the load on the works is likely to vary considerably over comparatively short periods. It assumes still greater importance when the works is heavily loaded and the acceptance of orders, especially on short delivery dates, requires very careful consideration. This can be considered its most important liaison duty, but it has a second, and almost equally important liaison duty, and that is to be in a position to give advice to the customer that the promised delivery date is going to be varied, either because it may be expedient to advance it or because circumstances make it impossible to meet it.

The Progress Department is not the actual producing medium, neither is it necessarily in control of the supply of raw materials. Nevertheless it accepts responsibility in the organisation for the co-ordination of all productive activity, it sees that due and proper attention is given to every operation on an order as it passes through the various manufacturing departments and eliminates delays between the several departments. It should also be responsible for determining the order in which the various operations will be processed, subject, where necessary, to technical considerations and to the convenience of manufacturing departments.

Many carefully prepared schedules for large scale production fail through time lost between operations or in a departure from the sequence laid down in the production schedule, and such failure can only be obviated by vesting in the Progress Department the responsibilities indicated. This can be taken as applying to production in both large and small quantities and to large and small manufacturing establishments.

It will be agreed that any paper presented on such an important aspect of manufacturing will be subject to the criticism that if it

suggests certain procedure as being highly desirable, it does not prove, except by implication, that it is commercially practicable or possible. It can be expected, however, that from the subject matter so presented and the subsequent discussion, sufficient ideas, previously proved or otherwise, will be forthcoming to assist all those concerned with the control of manufacturing units. Much of the subject matter now being presented has been evolved by a process of elimination or improvement from earlier or less effective methods.

Relation of the Progress Department to other Departments.

The relationship which the Progress Department bears to the rest of the organisation will vary in every works. In some it might be responsible to the directorate, in others to the works or production manager. This will naturally be determined by the general set-up of the organisation which in turn will be largely influenced by the type of plant and product and the personnel available. It can incorporate such work planning activities as jig and tool design, process layout, time study and ratefixing, but progressing activity can generally be equally effective if detached from them. Fig. 1 shows the relationship which the department should bear to the other portions of the organisations.

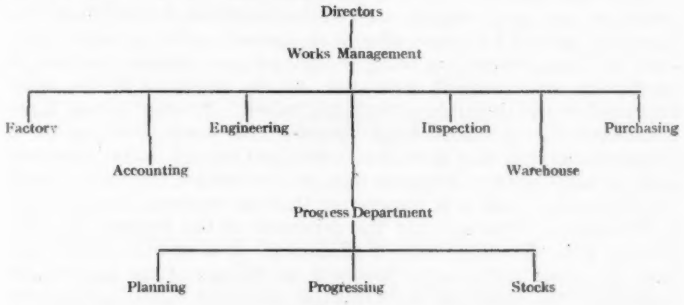


FIGURE 1

Provided that there is a maximum of co-operation and no attempt at shelving responsibilities, the Progress Department can operate successfully irrespective of the set-up of the rest of the organisation and for the purpose of this paper it is assumed that this somewhat ideal condition of maximum co-operation and full acceptance of personal responsibilities exists.

Personnel and Internal Organisation of the Progress Department.

It is important to realise that an individual of somewhat broad training is most probably the ideal type to be in charge of the

Progress Department. It is suggested that such a type would be found in an engineer who has, subsequent to his initial training, had a fairly broad manufacturing experience combined with some commercial experience. The engineering training would provide a sound basis for solving the many engineering types of problems which constantly arise. The manufacturing training or experience would provide a balance between the engineering solution and the possibility of letting the commercial end outweigh other considerations, whilst the commercial training would ensure that a thorough appreciation existed of the commercial, apart from the engineering and manufacturing problems.

The Progress Department, depending of course, on the size of the manufacturing unit, should be departmentalised on similar lines to the productive operations. It will generally be the case that progress men require the same general knowledge of the product as the various foremen so that it is unwise to expect them to spread their activities over too great a portion of the works. In addition to the sections directly associated with the manufacturing operations, the department might include a section for the handling of orders and another section for statistical records, unless these are provided elsewhere.

The organisation of the department and the selection of its personnel is of great importance and the department should not be a dumping ground for those who have proved misfits in other jobs. Just as " progressing " is being recognised as a definite function in production management technique, so the standard of the work expected of the department is being raised. It was, at one time, considered that a " good bright youth " was a suitable type for a progress man, but that definition is not good enough to-day, particularly in large works. Progress men can be trained from the " good bright youths," but it is imperative that the training is sound and well directed to ensure that the personnel of the Progress Department is kept at a high level of efficiency. It is of first importance that the department has a thorough knowledge of the layout and capacity of the plant and until this has been thoroughly appreciated by the department any effort towards a proper progressing of the work will be largely wasted.

Production Planning.

It is comparatively easy in an under-loaded works to produce to a schedule, provided always that the load on the works is sufficient to warrant the employment of an adequate labour force. It is particularly difficult on the other hand in an understaffed or overloaded works to get the maximum out of the available equipment unless the capacity of the equipment is well known. Whilst there is some natural hesitancy in suggesting that an additional department is interested in an initial layout of a new manufacturing unit,

nevertheless it is thought that many helpful suggestions would be forthcoming if such a layout is officially discussed with the head of the Progress Department who after all is the individual responsible for progressing work through it.

One of the greatest aids to production planning is to be found in flow charts or tables and their more general use would be helpful in both new or existing works. Charts compiled from adequate process time records can be considered as almost essential in the initial stages of scheduling production activities, especially when this scheduling is to be reasonably accurate over long periods. To suggest introducing work flow charts might sound somewhat formidable but they will generally pay for themselves time and again when properly prepared and used in the preparation of production schedules. Where scheduling is taken to the limit of predetermining fairly accurate individual machine loading, work flow charts are essential. If not prepared, it may be assumed that the information already exists in some form or other, and information such as this is better recorded on paper than carried around in the head of some member of the organisation.

The basis of flow charts or tables is the process time record shown in the following illustration, Fig. 2.

PROCESS TIME RECORD

PRODUCT—
PART—
MATERIAL

Operation No.	Operation Detail	Machine Tool	Class of Labour	Operation Time	Remarks

FIGURE 2

It will be seen that essentially the record consists of a descriptive or tabular statement of the productive operations, the equipment involved, the order in which the operations are performed and the process time. The process time record refers to individual details, and the flow chart is a summary, covering a predetermined period, of the process time records of all details included in the production planned for that period.

From flow charts, such as Fig. 3, it is possible to study not only the sequence of all operations but also generally get a much quicker grasp of the significance of this sequence. They are therefore of particular value when dealing with changes in the progress department staff.

A still greater potential value is their general usefulness when plant additions or reconstructions are under consideration. It is

suggested that the cost of preparation and study of flow charts would be amply repaid in many of the works which are to-day considered to be economical producing units.

FLOW CHART

Machine Department — Period (e.g.) June

Production Schedule and Item	No. off	Part	Weekly Mch. Hrs. Avail.																					
			Planning					Boring					Drilling					Turning					Milling			
	100	Coupling Flange	1st week	2nd week									100	100				430								
	Dates																									
Totals																										

FIGURE 3

Further aids to production planning result from the use of suitable graphs of which the following are examples :—

(a) *Sales and orders.*—A graph on which orders are plotted against time is often a useful indication of demand tendencies, and is therefore of assistance in making out production budgets.

(b) *Labour employed and productivity.*—If labour employed and production are plotted to the same time base, and a third curve added showing the production per labour unit, an indication is obtained of the trend of the manufacturing unit and of effects of changes in equipment and organisation.

(c) *Machine load factors.*—Curves can be drawn showing the percentage of working time during which the more important machines in the factory are actively engaged in production. They will serve as a guide to the efficacy of the production planning and assist also in reducing the losses associated with frequent set-ups.

Organisation of Activities Under the Control of the Progress Department.

Generally speaking the Progress Department has the option of manufacturing in the following ways : (1) By a controlled system

of maximum and minimum stocks ; (2) to a programme ; (3) by a combination of (1) and (2).

There is much to be said for either of the three general types of control available. A system of maximum and minimum stocks is simple to operate provided a satisfactory stock control system is available. It requires a very careful study of the demand, plant capacity, economy in machine set-ups, and co-ordination of the requirements where any interchangeability or similarity of products exists between departments.

The maximum and minimum figures set require adjustment which with a rapidly increasing or diminishing load should be done fairly frequently. On the other hand, with a steady load little attention is required except to take care of obsolescence. The system can work quite satisfactorily in any plant that is not overloaded, but as the general tendency is to set manufacturing quantities as high as possible to obtain the most out of any set-up cost, it has the disadvantage of being somewhat inflexible in an overloaded works.

The first requirement in such a system is a careful survey of the range of products and the demand that exists for them. It is then necessary to " break-down " the products into raw materials and parts and tabulate them in such a way that the schedule to be produced can be easily understood by all who are interested in the final result. Against the parts so tabulated are shown the minimum stocks it is decided will be held in the stores.

The calculation of such stock figures requires the setting of the quantities that will be adopted for the purpose of replenishing the stock and this, of course, requires some knowledge of general plant availability, economical set-up quantities, stock investment and possibility of obsolescence and introduction of new designs. The general formulae, however, is to set a minimum stock of such dimensions as will be sufficient to fulfil normal requirements during the period of replacement.

It will be found that, subject to certain limitations, such a scheme of stock control can be made to work quite well and economically, especially if the schedule is extended to cover certain additional information. The inclusion on the schedule, for instance, of the department in which the various parts are produced and the normal period allowed for the replacement of the stock permits the issue of production orders to be assigned to relatively junior clerks. This is possible, because on the receipt from the stock clerks of advice that minimum stock has been reached, all the clerk has to do is to prepare a new production order, the information for which is available from the schedule. A schedule which provides for all regular requirements is shown in Fig. 4.

MINIMUM STOCK LIST

Min. stock calculated on basis replacement within ____ weeks

Sheet No. ____
Date of issue ____

Item No.	Description	Cat. No.	Min. Stock	Mfg. Qty.	Purch. Qty.	Mfg. Dept.	Type Stock	Remarks

FIGURE 4

As already indicated, such a scheme has its limitations, but it can be operated successfully and economically when correctly applied. It requires the wholehearted co-operation of all concerned, together with careful and regular revisions to the schedules. It enables the preparation of bills of material in standard form which are available for issue as required, and when a bonus system of payment by results is in force, standard bonus sheets can be similarly prepared.

An essential is a reliable system of stock recording, but as this is frequently necessary both for accounting purposes and for long-range ordering, it is not necessarily a part of the general work of the progress department. All that is generally necessary in addition to the information already shown on a well-designed stock card is the minimum stock quantity in some prominent position where it can, and will, be automatically compared with stock balance figures as these are recorded.

An elaboration, generally comparatively expensive, is to keep flow charts of the form mentioned to ensure that the more or less mechanical issue of production orders for stock replenishment does not make demands on the plant that are impossible of fulfilment. When, however, it is commercially possible to do this, it would probably be preferable to depart from the system of straight-out minimum stock control and adopt more direct means of production planning or control.

Manufacturing on the second basis, i.e., to a programme, is probably more expensive in its initial stages than the controlled stock system. This applies especially when considerable detail is aimed at—and to be effective the programme must be detailed—since the preparation of the necessary schedules involves much work, and where there is a variety of production and the possibility of considerable variation in factory load the programme may require frequent revision. It does, however, remove from the shop in to the Progress Depar ment the responsibility of determining the order of production, and there is no doubt but what this is the

correct procedure where it is practicable. To this extent, therefore, it is likely to achieve considerable manufacturing economy when compared with the maximum-minimum stock scheme.

The preparation of production programmes and schedules pre-supposes some knowledge of the likely load on the works. Where this load is of a standard nature the schedules can be fairly accurately set months ahead, but where a large proportion of the output is manufactured "to order," then the schedules must be sufficiently flexible to enable these orders to be processed with a minimum of upset to other products. The first step is the preparation of an assembly schedule which shows the anticipated requirements weekly or monthly for the period, and this can generally be provided on a simple form, Fig. 5, which shows the total required over the period and the weekly or monthly batch quantities.

PRODUCTION SCHEDULE

Order No.
Schedule No.

Item No.	Description	Monthly Production						Total	Remarks
		Jan.	Feb.	Mar.	Apr.	May	June		

FIGURE 5

Simple in itself, this schedule is the most important in the general scheme, as inaccuracy in its preparation means inaccuracy in all the subsequent work. The second step is the breaking-down of the first schedule (which deals only in assembled pieces of apparatus) into parts. This permits the tabulation of a parts manufacturing programme. This parts programme, Fig. 6, can be prepared on the same general lines as the assembly schedule, except that it is desirable to provide for the inclusion of such allowances as excess parts carried forward from period to period, shrinkage during manufacture due to faulty materials, etc.

The nett requirements are those planned for, to which is added or deducted the shrinkage or surplus before the periods production is authorised in the shops. The difference between the total of these two figures and the actual production is the variation, from nett requirements to be provided for in the next shop authorisation. When this parts programme has been completed it is necessary to prepare a similar schedule outlining the raw material required. This is the schedule used by the buyer or stores department in procuring, by the dates required, the raw materials necessary.

PRODUCTION SCHEDULE (PARTS)

Order No.
Schedule No.

Item No.	Part		Monthly Production						Bal. Fwd.	Remarks
			Jan.	Feb.	Mar.	Apr.	May	June		
		Schedule qty.								
		Add shrinkage								
		Actual prod.								

FIGURE 6

Another type of programme which has been found to work quite well, especially on contracts spread over long periods, is a bar type of chart, Fig. 7. In this the assemblies, sub-assemblies and parts are listed vertically and the planned production shown by horizontal lines drawn under appropriate date spaces. It is possible on such a chart to keep a pictorial record of the progress of an order. This is particularly valuable on some types of orders, especially when the works are expected to produce a record which can be quickly and easily understood by those not intimately in touch with affairs. This type of chart has also frequently been used in the construction of large buildings.

PRODUCTION OR OUTPUT GRAPH

ORDER NO..... Due date.....

Part		MONTH											
		Jan.	Feb.	Mar.	Apl.	May	Jne.	Jly.	Aug.	Spt.	Oct.	Nov.	Dec.
A	Raw material production.												
B	Raw material production.												
C	Raw material production.												
Ass.	Raw material production.												

FIG. 7.

This chart must, of course, be supplemented by a schedule giving raw material requirements in detail.

General Observations on Systemisation.

There are, of course, innumerable types of forms that can be used for the scheduling of production. Generally the type used will depend on the nature of the product, the type of organisation and, of course, the amount of detail aimed at. If, for instance, each operation on every part is carefully scheduled, then accurate machine loading charts are essential. Some form of calculation is always necessary to avoid scheduling for the impossible, but great accuracy is not always either necessary or commercially possible. Provided that the schedule is possible of achievement, the simplest method adopted for achieving the desired end is the best.

To date or number production orders is one method of advising the shops of the order in which production is required. Another simple method is a control board on which is listed the equipment available, see Fig. 8, provision being made against each item of equipment for the filing of the production orders in the sequence in which they are to be handled :—

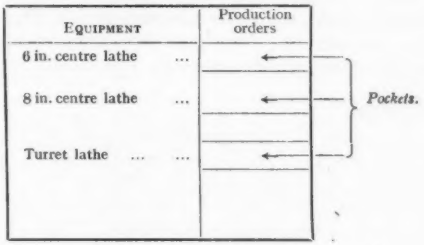


Fig. 8.

These are but two of many systems in vogue that attempt to achieve the result of a detailed machine loading chart whilst maintaining the maximum flexibility in the shops. It is imperative, generally, to maintain this flexibility because practically every manufacturing organisation has to contend with unexpected and rush orders that have the bad habit of upsetting plans which, because of the desire for too much detail, are generally inflexible.

The preparation of all these schedules or charts must take into account not only the anticipated demand but also the economical set-up quantities. When prepared they form the basis for the issue of production orders or authorisations.

It can probably be safely assumed that the capital tied up in stocks and work in progress would be lower for works with a 100% scheduled production than for a works where production activity

is controlled by any other method, and this is a particularly important aspect in a large organisation. There are, however, a preponderance of works where a combination of both schemes can generally be found to be most economical. In such works the general run of production can be programmed, and parts for which the demand is both small and variable can be satisfactorily worked on a maximum and minimum stock basis. This ensures reasonable manufacturing quantities for the parts of small and variable demand and eliminates the possibility of frequently interrupting the general run of production to work these parts through as they are required for assembly purposes.

Whichever system is adopted, the progress department must be provided with some form of budget or sales forecast and whilst it may be impossible to obtain a very accurate forecast from the sales or commercial people, they can provide sufficient detail to enable the Progress Department to forecast intelligently the load on the shops. In order to supplement the budget or sales forecast, the Progress Department must have available statistics which will permit them to apply the budget intelligently. Such statistics can be used as a yard stick for measuring the likely accuracy of the budget or determining for themselves the variation in load due to seasonal demand, which exists in practically every industry.

Job Chasing.

We now come to the consideration of an important aspect of the work of the Progress Department in which the human element plays perhaps the biggest part. That is the portion of its work generally called " job chasing " on which all the department's preliminary work either succeeds or fails. This work of job chasing is most important and this applies in every manufacturing organisation irrespective of the form of all the preliminary scheduling and planning undertaken. It is the job chaser that takes the schedule of production and by one or all of the known arts of persuasion gets the raw material on to the floor of the works and the finished article off the assembly bench by, if possible, the scheduled dates. The task is never easy but strangely enough his biggest job is not so much to get the actual work performed within the time allowance as to get it started on the date shown in the schedule.

He has to ensure that sufficient pressure is brought to bear on the suppliers of raw materials so that this potential source of delay is reduced to a minimum, if not entirely eliminated. This in itself is not easy and even might involve the chasing of raw materials used by the supplier himself. As the result of this work the Progress Department quickly becomes aware of the reliableness of any promises given by outside suppliers and can, if necessary, ask those responsible for purchasing to concentrate as much as possible on

those whose service is good and whose deliveries are reliable. The knowledge is of further use in providing the department with some knowledge of the load on the works of outside suppliers and in this way permits them to use better judgment in scheduling their requirements.

In some form the job chaser is made aware of the dates by which completion of orders is expected. Having taken the necessary steps to ensure, as far as possible, the supplies of raw materials, it is necessary to follow the material through its various stages of production, eliminating the delays that will otherwise surely occur between the various production processes. It would seem that it is generally not commercially possible to use any very satisfactory system for following up orders in which the initiative of the individual does not play a most important part. This is in itself useful, as no part of the Progress Department's activities would so lend itself to over-systemisation as the work of the job chaser. Illuminating records could be compiled, but because they were of past happenings they would be largely useless. What is generally required is not to know that something did not work out to schedule, but that adequate steps were taken to keep it as near the schedule as possible.

Just as the preliminary work of the department attempts to forecast the future, so the job chaser in attempting to put the forecast into effect must also look well ahead. There is, however, wisdom in the use of some form of tickler system to assist the job chaser. Such a tickler system should be designed to bring all the orders, if possible, up for review during the most important stages of production. It should be used as the medium of preparing progress reports to the commercial departments, where these are required. It is also the record by which the Progress Department is able to determine the possibility of effecting delivery within the specified time allowance and from which revised dates, if necessary, are advised.

Where the acknowledgment of orders is a function of the Progress Department a copy of the acknowledgment, showing the promised delivery date, can be used in the tickler file. If a more convenient form is desired, a card can be prepared at the same time as the order is acknowledged. The record of the progress of the order as recorded on the card, if suitably filed on completion of the order, can form a useful guide for the future and is also a means of determining with some measure of accuracy the effectiveness of the various sections of the organisation involved.

Such a card, as shown in Fig. 9, in addition to describing the nature of the order, should show the date of its receipt, the estimated and actual dates of the issue of working instruction, the delivery

promised date and the revisions, if any, to this date, and, of course, the actual date of despatch. Where practicable the reasons for revising delivery dates should also be shown.

HISTORY CARD

Sales order—
Date Received—

Description—

Works order—
Date issued—

Instructions—Due for issue—
Actually issued—

Delivery date—
Revisions 1.
2.
3.
4.

Notes:

Date despatched—

Fig. 9.

It is, of course, possible to include information of a much more detailed nature on such a card, and on the other hand it could probably be quite effective with even less.

The work of the job chaser will be simplified if care is exercised in the method adopted for the issue of the production orders. These should be issued when they are required in the shops and not sent out of the Progress Department, as and when prepared. There is nothing to be gained and probably a lot to be lost by having unnecessary manufacturing information in the shops.

Conclusion.

The work of the Progress Department, its potential value in the maintenance of customers' goodwill and its possibility of effecting substantial direct savings in manufacturing costs are not yet fully appreciated. Perhaps the day is not distant when the need for the collection and co-ordination of data for use by Progress Departments in their aim to achieve 100% effective utilisation of machine and man power will be fully appreciated. Nevertheless the Progress Department must never lose sight of its commercial responsibilities. Its first responsibility is to assist the commercial departments in their essential aim of creating an ever-widening circle of satisfied customers. It should not therefore aim at—and should never be permitted to develop—a type of control that will not be sufficiently flexible to take care of the rapidly varying demands and sometimes unreasonable requirements of that most important individual, the purchaser.

Discussion.

MR. S. D. MCPHEE: One thing that appealed to me was the question of layouts. Most of us who have studied this subject know the extreme value of layouts. We call them layouts, Mr. Barratt calls them "work flow charts." We call one thing one name, others use a different term to what we do; there is no common nomenclature in use, and this could be one of the most valuable results of our meetings.

Work flow sheets are most important, and most factories have, at some time, to solve, the problem of when these should be incorporated into the factory organisation. I belong to Standard Telephones and Cables Pty., Ltd., and we are a small branch of an organisation overseas. In the large branches overseas they have work flow sheets throughout the factories. Our local organisation investigated this matter and found that too much non-productive work was required to prepare and keep up to date these flow sheets and the detailed machine schedule to be prepared from them. In our early years, we had to go along as most small factories have to do, trusting to foremen remembering, from one period to another, just how a job was done, and trusting to the general commonsense and knowledge of the production control people, i.e., the processing control people, and foremen in consultation together, to arrive at the capacity of the ship and the time required to carry out orders in hand. The important question I am raising is, at what stage, in the experience of Mr. Barratt and others, does it pay to put in the work flow system, and how is one to know just at what stage it will pay?

MR. BARRATT: Dealing with the question of nomenclature: most other professions during the last century have got together and, as a result, have decided on the use of certain names or titles for specific purposes. We production engineers have relied on terms used in text books and also largely on our imagination, and because of that have reached a stage when, not only does Mr. McPhee and other members experience difficulty in following my paper, but also in understanding certain of our text books. I think it would be appropriate for our section to suggest to Institution headquarters that steps should be taken towards standardising titles or names to be applied to certain forms used for similar purposes.

In regard to the question of the introduction of such refinements into the progress department as work flow charts, this is a question that cannot be answered easily. Personally, I think it is not only a matter of the size of the organisation, nor of the type of the product, but largely a combination of both. In a factory that is mechanised, being fitted with rapid handling facilities, air hoists,

automatic lathes, and special purpose tools, employing, say, 100 men, I think the work flow chart is essential. On the other hand, a factory not so mechanised and possibly employing 1,000 men will probably get along quite well without them. Perhaps the next decade or two will produce some formula that will show us that it is desirable to spend extra money on such systems. There is no formula at present that will help us to sell the idea to those responsible for the opening of the purse strings.

MR. C. G. CRANE : I would like to ask Mr. Barratt if he has ever used the production board system, in which each machine is listed vertically and the intervals of work, may be work days or weeks or fractions of a month, are listed horizontally? As the work is scheduled through the shop, a little tag is put on this board, showing the time at which the particular operation should end and the next operation for the machine should follow on. It is very simple to see the load on any particular machine by the number of days, or work intervals, covered by the tags in the horizontal line for each machine. I have used this method very satisfactorily and have been able, by putting forward some jobs, to even out the load on our machines with a very considerable elimination of idle time and of the setting up time that is often necessary when a machine is overloaded and production requirements cannot wait the completion of a long run on one particular job. I have not heard of, or seen this used, elsewhere, and would like to ask Mr. Barratt if he has seen it or any developments on it.

MR. BARRATT : I have never actually used, or seen used, the type of board you describe, but have used the type of graph I displayed during the course of the paper. Really the type of board you describe is similar to this graph, except that the machines are shown vertically instead of the product. We have been using a graph, similar to that indicated, showing load on certain items of plant measured in 100 hours, but the board would probably be more useful, as it would be kept in the shop, whereas the graph can only be kept in the office.

MR. W. F. DAWSON : I have listened with interest to what has been said to-night and have found it very instructive. I would like to give a short résumé of a simple system we adopt in our shop. The progressing of work through the shop, particularly if only a small shop, is rather difficult, and, as Mr. McPhee wisely asked, when should the chart be used, and as Mr. Barratt said, it is very difficult to answer that question.

In our small shop we employ about 70 men—previous to that I was looking after a shop employing 300 to 400 men and we used exactly the same system with slight amendments—and are at present running two shifts. We have to be able to leave the second

shift fairly well provided for so that, if anyone runs out of a job, his foreman can immediately pick up material and tools that are there to hand.

The procedure we adopt after getting an order—and we are getting plenty at the moment—is that the order clerk first makes out the order on a duplicate folio. If the product is not kept in stock, or is a special job to be made, it goes to a junior draughtsman, who sketches out the job. This is done irrespective of the size or quantity, as we consider that any job that is worth doing is worth a sketch. We have upwards of 6,000 to 7,000 of these products cards, which are about 8 in. by 10 in., filed away. If an order is repeated by any company, we turn up the previous card and the job is there already sketched out. At the first time of manufacture all details necessary for the production of the job, the amount of material required, the tools and machine on which the operations have to be performed, are all shown.

The card first of all goes to be checked to see that all necessary details are shown, and then goes out to three pockets. These pockets are just outside the office inside the store—only a small store, but still a store. First of all the card goes into the top pocket. The storeman comes along and takes the card out of the top pocket. The material required for the job is listed on that card. He looks to see if the material is in stock, and, if so, the card goes down to the third pocket. There might be issued with the card an operation chart; it depends on whether the operations can be detailed on the card, or whether there are too many for the card. If there are too many, then an operation chart is made out.

As already mentioned, if the material is in stock, the card goes into the third pocket, and if not in stock it goes into the second pocket. In the second pocket it has a blanket sheet or blanket requisition form. The storesman may find that half a ton of material is wanted. He puts the card in the second pocket and on the blanket requisition he writes down the material of which he is short.

There is also a fourth pocket, which is for the toolmakers, as every job wants tools, unless standard. The toolmaker comes along and looks to see what tools are required, and if in stock or standard, and this goes on the card in the fourth pocket. Any card in the fourth pocket shows the material and tools ready to be issued to the shop. The cards are taken from the fourth pocket, may be a couple, may be a dozen, to the production board in the shop, and on that board every machine in the shop is noted—we have about seven turrets of the one make—have others, but seven of one make, which all go on one tag. All the machines are tabulated on top of tag and also to which machine each job belongs. When deciding to do the job on one turret, the job is hung on the tag.

By this means one can tell at a glance how the shop stands, and can tell in a hurry what work is in hand for any afternoon or night shift. It is only a matter of looking at the board to see just exactly what has to be done—may be three or four set-ups on machine if only small quantities. All particulars are on the production board. The materials are right, the tools are right, and all that has to be done if an operator runs out of work is for the foreman to see that the material is taken to the machine and the tools collected from the store.

One other point ; if short of material and the card is put in the second pocket, I take the blanket requisition card, or it is taken by the junior draughtsman, every night, and see what is wanted, and it then goes to the order clerk, who makes out the order, and when the order is made out the blanket requisition is marked "M.O." in red pencil, and then it goes back into the pockets which are hung in a sort of bucket, until the material comes in. When the material arrives, the card is taken from the second pocket and we check what has come in with what was ordered. Mind, there is only one sketch on each particular order card, not several items. If you have several items on one card you will run into trouble One sketch on one side of each card, each card the same size, and they are easy for filing.

If No. 1 operation is finished on the shift to-night, they are reviewed in the morning, and, when the cards are finished, they are placed on racks, and they are collected from the racks, sorted out in front of production board. As mentioned above, one has only to glance at the production board, marked with every machine, to tell instantly if the machine is loaded. It will not tell how many orders on that machine ; this can only be told by looking on the operation chart and on the order cards, and these all added together give the total number of orders per machine.

I do not see anything against this system, even if we were employing 600 men. It is simple, and nearly every system to be efficient must definitely be simple. As I say, we have been running this scheme for about fourteen or fifteen years, but the main thing is to see the reshuffle of all order cards after finish of each day or night shift—either every morning or every night, but at a definite time every day, and place on production board on the machine on which job is to be done. This method does not keep up to deliveries —perhaps some other system is wanted for that, but, generally speaking, I find in the majority of cases the customer keeps one up to that.

MR. A. B. HOPKINS : In a shop doing production work as well as jobbing work can one use the work flow chart where jobbing work is nearly as big a factor as the production side of the shop ?

MR. BARRATT : I think that is a question that can only be answered by experience. It should be possible to use a flow chart on a combination of jobbing work and repetition work, just as it is possible, where big plant is involved, to use flow charts on straight-out jobbing work. The extent to which they should be used is a matter of individual opinion. A factory engaged on a combination of repetition and jobbing would find some kind of load chart very useful. If a shop engaged on repetition work is to try to satisfy customers by maintaining delivery dates it is essential to know in some detail, and this applies to both large and small factories, the amount of load existing on a machine, group of machines, or even on a whole department, and of course the extra time required to produce anything of an " off-standard " nature. I feel that if the type of factory you describe is giving delivery dates for jobbing work without having some definite knowledge of machine and departmental load, it will be found that one of two things are happening. Delivery dates are given, the keeping of which involves sacrificing work on the regular mass production jobs, or, alternatively, the mass production work is being done and no serious effort being made to deliver other work within the specified time. I think it is largely a matter of experience, and also, as pointed out by Mr. McPhee, the size of the factory. In a small factory, say, of up to 100 or 200 men, one or two people are able to keep in mind a fairly accurate idea of the load on the machines and departments, but, as the plant becomes larger, and when delivery dates are given by a section of the organisation which is not directly in charge of productive activities, I think it is not only desirable, but necessary, to have work flow charts.

MR. H. M. JOHNSTONE (in the Chair): Our function, as an institution of this kind just starting a new section in Australia, should be, I think, to try first of all to co-ordinate all ideas brought forward to cover the particular conditions applying to Australia. Most shops in Australia have developed on peculiar lines. I am speaking from experience of thirty years in different shops. The type of shop in Australia was more or less a job shop up to the time of the War, but since then companies and factories have had to develop more particularly on the lines of mass production. It follows, therefore, that there is a demand for some system, or system of control of all the aspects of production, whether the company is producing large or small quantities.

We in Australia have not had the experience of the overseas shops, but I think we are now getting to the stage when we must give the matter serious thought, which opinion is borne out by the attendance here to-night and by the reception the Institution of Production Engineers has had so far in Australia. Mr. Barratt's paper to-night has been too comprehensive for us to absorb it all

immediately, as it covers such a large field, but it has instantly brought forward a discussion from which I would like us all to take away to-night one or two points at least to think over. Firstly, there is the idea brought up by Mr. McPhee regarding the necessity of having some standardised forms, or standardised names for various forms, and good work could, no doubt, be done in developing something of that nature.

Secondly, we must realise that different shops must have slightly different systems, depending to a large degree on the class of manufacture. In the case such as Mr. Hopkins mentioned, where there is a mixture of jobbing and mass production work, this is an extremely difficult problem, and merits much thought. Mr. Dawson outlined in a very interesting way the procedure his company adopts with a comparatively small personnel, which sounds to have a lot of common-sense. I feel there is much for us to think about along the lines of these points, and that we can, in general, take away with us to-night much for consideration.

REPORT ON THE SEVENTH INTERNATIONAL MANAGEMENT CONGRESS.

By U. Baliol Scott, British Management Council.

THE papers and discussions of the seventh International Management Congress may not, in themselves, have been sensational. Yet their implications are far-reaching and indicate that the future character of our social, economic, and political institutions will depend more upon management than any other factor in our life to-day. The following were some of the outstanding conclusions from the general sessions of the Congress.

(1) Management is *not* ownership. The manager's function as a member of a new profession, discharging both executive and judicial responsibilities, was described with greater clarity than ever before. There was no dissent from the view that one of the manager's primary duties is to act as a judge or umpire—weighing the just claims of all parties in the economic system—labour, owners, consumers, and the public.

This conception of the manager as a representative of all groups rather than as the paid functionary of capital is extraordinarily important. Neither the workers nor the representatives of government have yet fully grasped this essential change in the balance of forces in the business world. Combined, however, with this recognition of the separate status of management, there was the realisation that the workers generally considered that management costs too much, that while managers should share in the profits which have accrued from their management, the remuneration for management is disproportionate.

In a short view of the situation there was thus a tendency for management to be biased in favour of the owner. In the long view, however, it was seen that good results can only be continuously maintained if the management keeps a just balance between the claims of all parties.

(2) Management is more alert than ever before to its social responsibilities. It regards as part, if not the most essential part, of its function an obligation to concern itself with the solution of the vast and complex social and economic problems which affect the consumer, the worker, the owner, and the public. The methods by which these problems are to be solved may largely lie in the field of the unknown. But the first step in their solution is obviously

that management should think about them seriously and continuously.

Business is becoming humanised. The Congress showed clearly that all problems, whether in business or government, are ultimately " human " problems—that relationships with employees, safety and health considerations, tenure of employment, security and analagous questions should be studied more intensively. Humanity is not to be confused with " kindliness " or " paternalism " on the part of the employer. The end to be kept in view is the development of a relationship in which employer and employee are equals with equal respect and consideration for each other and each other's difficulties.

In emphasising the concentration of the Congress upon the social problems arising in business, it is recognised that the most enlightened management has always accepted a large share of this responsibility. It has, however, been suggested that American business is taking up the problem of social obligations primarily because it is now convinced that if it does not the Government will step in.

It has been pointed out that there is a definite objection to Government interference, and strenuous efforts are being made to prove that it is unnecessary, and these efforts are tending to produce completely self-contained businesses whose constitution envisages acceptance of complete responsibilities for its personnel, that is, controlling of the social and economic conditions of employees (sickness, unemployment benefits, etc.), as well as of their working and remuneration conditions.

(3) Self-analysis and self-judgment are the surest means of stimulating thought and developing new ideas bearing upon the problems of business. Management demonstrated that it is willing to learn ; that it is conscious of its shortcomings in the past, and alert to its future opportunities.

(4) Business is a vital and integral part of the community's life. Leaders in industry must accept their responsibilities to the general public and can no longer live in isolation. The function of " public relations " is thus attaining a new status. It is no longer regarded as a subsidiary activity to be entrusted to some employee who is not otherwise fully occupied. The function must be given a major status. It calls for continuous operation and merits study and effort of the highest quality.

To make a good product and to secure good industrial relations within an enterprise were recognised as most important factors in its relation with the outside world. There was no dissent from the view that the everyday things a company does are the most vital factor in its reputation and, that in the long run, the sum of these actions will outweigh any other phase of public relations work.

In the words of Arthur W. Page, speaking at the Congress:

"Public relations, in this country, is the art of adapting big business to a democracy so that the people have confidence that they are being well served and at the same time the business has freedom to serve them well. If the reputation of big business is good enough with the public, no one representing the public, whether in press, politics, or any other capacity, will be hostile to it."

(5) Management is everyman's concern since it occupies a key position in the process of providing society with what it desires. Karl T. Compton, President of the Massachusetts Institute of Technology, outlined the vital role of management when he said: "... The unemployed want work, industry wants profits, agriculture wants new uses for its products, natural resources ought to be more wisely used, national hazards should be curtailed, labour wants shorter hours and higher pay; all the people want more wealth, lower income taxes, better health and comfort, additional facilities and commodities. Every one of these desirable social developments can only be realised through the action of two forces, the force of better technical developments and the force of better management." The idea of management becomes concrete when it is viewed as the effort to link workers and machines together so as to achieve for all both a higher standard of living and a greater measure of security.

The General Sessions of the Congress thus emphasised that management is now envisaged more clearly as a separate function; that it is becoming more human and is demonstrably more alert to its social responsibilities; that those in positions of responsibility are by no means content with their achievements, being inclined to look forward for new opportunities rather than backwards to what has been accomplished; that they are more sensitive to public opinion than at any previous time; and that in the task of achieving a progressive and stable society, management occupies a key position.

Points from Technical Sessions.

As in the case of the General Sessions, the dominant feature of the discussions at the Technical Sessions was the recognition that in the handling of human problems, science alone is not enough. There were abundant signs of a greatly increased sensitiveness to and desire for an analysis of those deepseated human and social problems which have seemed hitherto to be outside the immediate concern of industry. The practical handling of human affairs involves a sphere of action where science, although it remains man's only source of information, is not of itself sufficient for the solution of the problems encountered.

The conscious training of those who are going to hold administrative and managerial posts thus emerges as a factor of enhanced importance and becomes increasingly a matter of acquiring an art in addition to learning a technique. Training in those sciences which have contributed to the creation of a new industrial order remains a necessity but is no longer sufficient in itself. Additional practice is required in human and social investigations and in the habit of human responsibility.

It was realised that the qualities required for leadership could not be obtained merely by the provision of special courses; that character and personality are qualities which require suitable background and environment to develop, and that it should be the personal duty of the present leaders in industry to train their successors by contact and influence. It was felt that this personal training by example could do more than any other single factor to ensure that the latent talents of the leaders are brought to fruition. From the point of view of the employee, this awakened consciousness of the human aspects of management was to be seen in discussions centring round the tendency for management to conform the process to the men rather than the man to the process.

In discussing the relationship of management to the employee, the employee was seen as a co-ordinate human being and it was recognised as desirable to have the employee become more money conscious, to have him thinking about doing things as cheaply as possible and to develop in him a consumer consciousness. Serious attempts were also being made to assess on a scientific basis the reward appropriate to skill, service, reliability, initiative, and all the other factors which are made use of in doing a job. It was felt that something further than the normal working of the laws of supply and demand and collective bargaining was required, and the problem was considered to be a subject for early research.

From a technical standpoint there was a general feeling that the application of scientific management ideas had tended to increased complexity, and the view was expressed that the time was ripe for a reconsideration of organisations, methods, and records with a view to simplification and increased flexibility.

Points of interest in the field of production management included:—

(1) Industrial research should more nearly approach scientific research, in that the results should not be kept secret, but made available to all.

(2) The idea of preventing as much as possible the more serious fluctuation in the productive process by providing the following: (*a*) A greater operator versatility, with workers able to do more than one job; (*b*) increased preparedness for fluctuations through

more flexible budgets and other controls; (*c*) provision against seasonal fluctuations by the development of fill-in products and added storage space.

(3) Approval of the decentralisation idea.

(4) The changed managerial attitude to: (*a*) The suppliers—the people who sell to manufacturers. The purchasing agents are learning that the salesman can aid in the whole process of purchasing and manufacturing; (*b*) more thinking by those engaged in the productive processes about the consumer, and the "why" of the thing they are making.

In the administration section two pre-eminent conclusions emerged from the discussions. In the first place the absolute dependence of human society upon good administration under social, economic, and psychological conditions of rapidly increasing complexity, was made abundantly clear. A second and complementary conclusion which emerged concerned the growing complexity of the variables and influences which play upon the administrator and which render his task daily more complex. The administrators were seen to be exposed to a three dimensional growth in the range of forces with which they had to contend. First, as the administrator climbs up the ladder of his own business his responsibilities shift from the technical to the broadly managerial, with a higher degree of responsibility for dealing with forces outside rather than merely inside the business. In the second place, as the units of business grow larger the social responsibilities and difficulties increase. And finally, the social environment in which the administrator operates is changing with startling rapidity in almost all the countries of the world—and the task of the administrator is made enormously more complicated by new facts, situations, and values.

HARDNESS TESTING

Paper presented to the Institution, Sheffield Section, by J. Woolman, M.Sc.

DURING the last eighteen years during which the author has been engaged in the field of testing materials, there has been a considerable development in the field of hardness testing. At the beginning of this period the Brinell hardness test had become more or less firmly established, but we were limited to the 3,000 kg. machine. It is true that by taking up all the weights we could operate this machine with a load of 212 kg. and with this load and a $^{3}/_{32}$in. die ball we were capable of making relatively low load tests but there was no special machine designed for this purpose. If thinner material had to be tested than was capable by this arrangement, various subterfuges were necessary. The only other hardness testing machine on the market at that time was the Shore sclerescope.

It was clear, therefore, that the time was ripe for the introduction of a low-load Brinell testing machine and indeed we had at the Brown-Firth Research Laboratories insistant demands for such a machine. The reason for this was because at that time stainless steel cutlery was being made in greater and greater quantities. The cutlers who were used to making carbon steel knives did not readily adapt themselves to the quite different heat-treatment required for stainless steels, and in consequence the new steel was being finished in a condition which was soft and unsuitable for its purpose. This was one of the reasons why stainless steel in the early days got the bad name that it would not keep its cutting edge. The cutlers, therefore, required a simple and cheap instrument with which they could ensure that their stainless steel knives were supplied with the correct hardness and as no such instrument was available one had specially to be designed for the purpose. My colleague, Mr. Stanfield, designed such an instrument in the form of a pair of nippers, the load being controlled by a spring arrangement, and this little machine was adequate for immediate needs. Its scope, however, was limited—e.g., its operating load was 180 kg. which did not permit testing very thin sheet material and the Firth hardometer was subsequently designed at the Brown-Firth Research Laboratories. This instrument has been subsequently improved by collaboration with the engineers tool department of Messrs. Thos. Firth and John Brown, Ltd., and efforts are being to make this

instrument of as wide an application as possible. The development of these instruments has necessitated us making a special study of the subject of hardness testing, and in this lecture it is the author's endeavour to give the results of the experience gained on this subject.

What do we mean by hardness ? This simple question is difficult to answer, and numerous definitions have been suggested. All, however, are not adequate in that they are not sufficiently comprehensive. The fact is that there are several different kinds of hardness and they are not entirely related. The general conception of hardness is the one usually obtained by feeling an object. We say that an object such as rubber, soap or modelling clay, which gives way under the action of finger pressure is soft, and substances such as stone, steel and diamond which do not do so are hard. A scientific term for this conception of hardness is " resistance to deformation," but this definition can be interpreted in two ways. For example, rubber easily deforms under pressure, but recovers itself on removal of the pressure. Sealing wax on the other hand, although not so readily deformed under the action of pressure, permanently and slowly deforms under the action of quite low stresses.

We therefore speak of " resistance to permanent or plastic deformation " and " resistance to temporary deformation." In both these forms of hardness the time factor is frequently very important as we have already indicated in the case of sealing wax which under rapid loading has very low ductility and a relative high resistance to plastic deformation. Both these types of hardness must, therefore, be further qualified as to whether the load is of the static or dynamic type. The time factor is more important with soft metals than with harder ones. This point will be referred to later when dealing with various types of testing, but it will be appreciated at this stage that dynamic forms of test such as the Shore sclerescope or impact Brinell cannot safely be correlated with static forms of test such as the ordinary Brinell or Rockwell tests.

There are other types of hardness—e.g., scratch hardness and wear hardness or resistance to abrasion. Machinability is another form of hardness. These again are not entirely related to the usual indentation forms of hardness. The scratch test was perhaps the earliest form of hardness test and is still used by petrologists for grading the hardness of minerals. The scale in common use is the Moh scale. In general, the range of hardness met with in steels covers only a very narrow region of hardness in the Moh scale.

The file test is a modification of the scratch test and is still in considerable use. The results, however, are frequently misleading.

The author will deal mainly with that form of hardness defined as resistance to deformation. It is a controversial point whether one should consider in this connection the permanent deformation or the temporary deformation which includes both the plastic and elastic deformations. Opinions of different authorities are divided. However, from practical experience it is known that for materials of similar type the Brinell test bears a close relationship with the tensile strength of a material and as also this form of test is simple to carry out, it and similar forms of permanent indentation tests have been more or less generally adopted. Actually as the elastic recovery for most metals is only a very small proportion of the whole

STATIC INDENTATION TESTS

Geometrical form of indenter	Rigid tool as indentor	Specimen itself as indentor
Sphere.	Brinell. Shore "Monotron." O'Neill. Poldi tester. Type (*d*) } Type (*a*)	Hertz. Auerbach. } Type (*c*)
Cone.	Calvert & Johnson. Kerpely. Ludwik. Rockwell. } Type (*a*)	Mallock. Type (*b*)
Cylinder.	Kirsch. Type (*a*)	Foppl. Cowdrey. } Type (*c*)
Prism.	Keep. Unwin. Smith & Sandland (*e.g.* Vickers & Firth tests). } Type (*a*)	Reaumur Chisel test. Type (*b*) Reaumur Prism rest Haigh. } Type (*c*)

FIGURE 1.

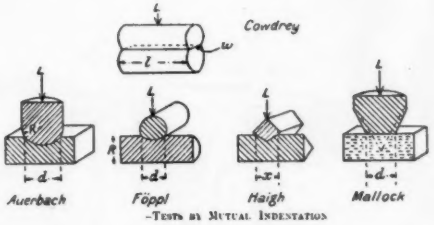
deformation the difference for practical purposes between the two forms of tests is relatively insignificant.

The subject will be dealt with essentially from the practical standpoint, and an endeavour will be made to indicate the precautions necessary to obtain reliable results.

Fig. 1 gives a table summarising the various forms of static hardness tests taken from O'Neill's book on hardness. The column on the right gives various forms of test, utilising test pieces cut from the material under examination in which two pieces of the same material are mutually deformed under the action of an applied force between them as shown in Fig. 2. Such tests we found very

useful before the days of the small load Brinell machine—e.g., for estimating the hardness of small wires in the manner of the Foppl test. The prism form of tests—e.g., the Haigh is practically independent of the load as the impressions are geometrically similar.

We will now consider the various forms of static indentation tests.



—Tests by Mutual Indentation

Fig. 2.

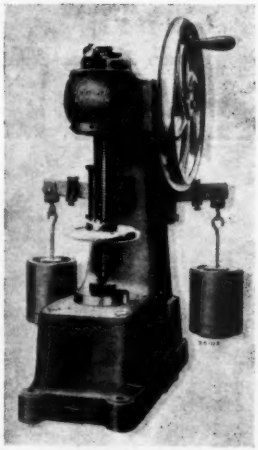
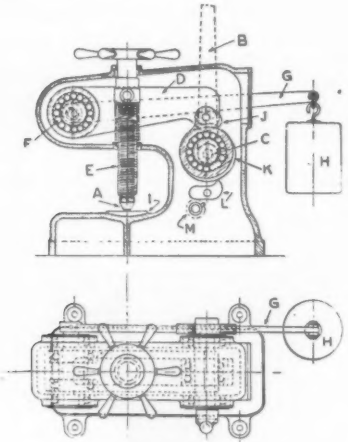


Fig. 3.—Brinell Hardness Tester.

The most widely used test of this type is the Brinell test in which a hard steel ball is pressed into the surface of the material tested. This form of test is perhaps the best since it gives a quantitative measure of hardness in the correct units.

There are three factors which control the accuracy of hardness test.

(1) *The Load.* One is usually at the mercy of the suppliers of the instrument as regards the accuracy of the load applied, but where standard check test pieces are provided they should be used frequently to ensure that the load is maintained at the desired value. In all instruments, the load should be applied gradually to avoid overloading on account of inertia effects.



—Johnson Machine.

Fig 4.

(2) *The Indentor.* Ball and diamond indentors nowadays are very reliable, but in the case of ball indentors one should always obtain balls specially made for hardness testing.

(3) *The Measurement of the Impression.* Where the hardness is obtained by measurement of the diameter or diagonal of an impression by means of a microscope one should frequently check the accuracy of the microscope by use of a standard scale. The microscope should only be used when it is in correct focus which can be ascertained by moving the eye slightly sideways when, if the instrument is in correct focus, the edges of the impression will not move relatively to the scale divisions of the microscope.

Figs. 3 to 7 illustrate various types of static indentation testing machines of the Brinell type. These are not intended to give a complete list of such machines or to indicate that they are the best available. They are merely indicative of the various kinds of

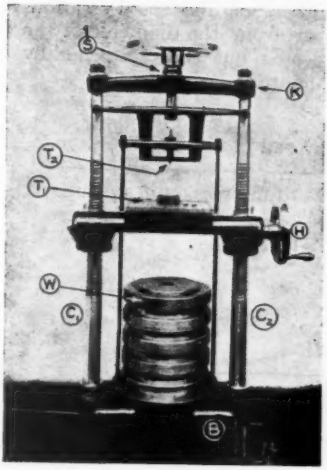


Fig. 5.—Small Ball Machine.

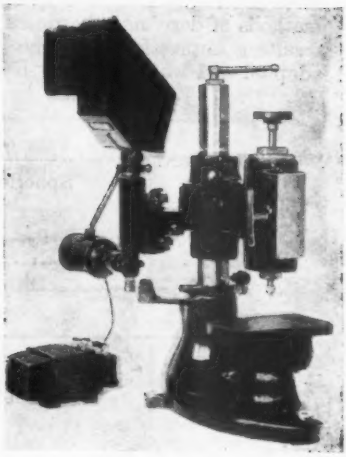


Fig. 6

Fig. 7.

machine on the market and have been chosen as the author has had more experience with them than with others not illustrated. Various methods of deriving a hardness number from the diameter of the resulting impressions have been suggested but the one generally adopted and which has now been standardised is :—

$$\text{Brinell hardness} = \frac{\text{Load in Kg.}}{\text{Spherical area of impression in sq. mm.}}$$

$$= \frac{P}{\pi Dh}$$

$$= \frac{2P}{\pi D^2 \left[1 - \sqrt{1 - \left(\frac{d}{D}\right)^2}\right]}$$

P = load in Kgm.
D = diameter of ball in mm.
d = diameter of impression in mm.
h = depth of impression in mm.

One of the upsetting features regarding ball test is the fact that the impressions are not all geometrically similar, so that if different loads are used with the same size of ball the hardness numbers obtained are not in general identical, as shown by the results of tests shown in Figs 8, 9, and 10. This feature has given rise to a great deal of investigation but as far as we are concerned it is sufficient to note that if impressions are geometrically similar, that is if $\frac{d}{D}$ is the same, then the same hardness number is obtained provided $\frac{P}{D^2}$ is constant.

This is found to be true in practice provided that the material is uniform in hardness throughout the thickness.

For steels the value $\frac{P}{D^2}$ should always be 30, e.g., 1 mm. ball with 30 kg., 2 mm. ball with 120 kg. or 10 mm. ball with 120 kg. Figs. 9 and 10 show the departure from the standard Brinell figures when other values of $\frac{P}{D^2}$ are employed in steels of different hardness values. Fig. 11 shows similar curves given by Brownlow for

different samples of copper. Values of $\frac{P}{D^2}$ other than 30 are standardised for non-ferrous metals, e.g., a ratio of $\frac{P}{D^2}$ =

10 for hard copper alloys;
5 for soft copper and similar metals;
1 for lead and other very soft metals.

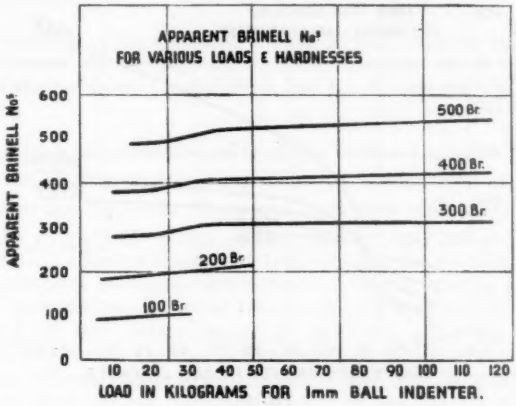


Fig. 8.

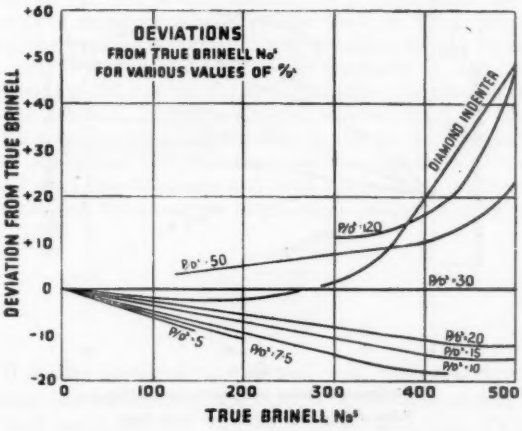


Fig. 9.

In general the best ratio to use for a group of alloys is one in which the middle of the range of the series has a Brinell impression with a diameter about three-eighths of the ball diameter. The results

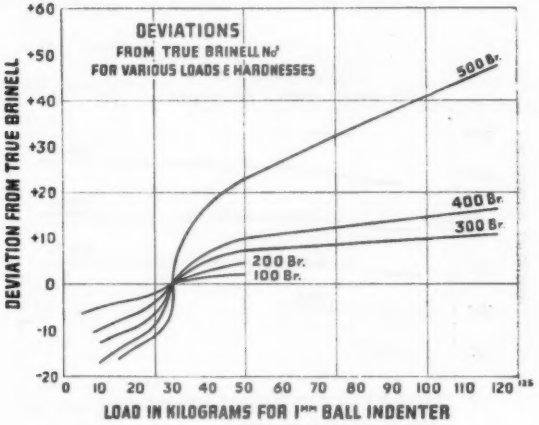
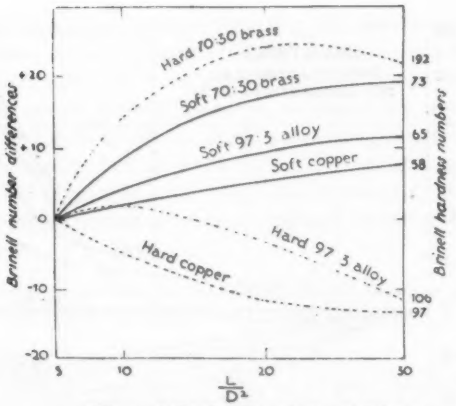


Fig. 10.



—Differences in Brinell Hardness Numbers for Different Values of $\frac{L}{D^2}$ for Copper, 97 : 3, and 70 : 30 Brass.

Fig. 11.

are not very satisfactory when the impressions are less than one-quarter or greater than three-quarters of the ball diameter.

When testing small pieces the results are liable to be erroneous if the centre of the impression is less than twice the diameter of the impression away from the edge of the specimen. B.S.S. specify two and a half times the diameter in this connection.

The thickness of the specimen should be such that the impression does not show on the underneath side. Usually seven times the depth of the impression is sufficient, but B.S.S. now specify 10 times the depth.

I have previously mentioned that the hardness number obtained is the same if $\frac{P}{D^2}$ is constant provided that the material is uniform throughout the thickness. Departure from such uniformity may be the result of various causes. Softer surfaces may result from decarburisation effects during heat treatment or by scorching effects during grinding. Surfaces harder than the interior may be produced by case carburisation or other case hardening treatments, by work hardening of the surface layers by grinding, polishing, or other excessive cold work during the preparation of the surface, or by scorching effects during grinding where such scorching effects are so severe that surface layers of the steel are heated above the critical range and following subsequent rapid cooling such surface layers are actually submitted to a hardening treatment. It follows that some care should be exercised in the preparation of the surface and excessive pressure should not be used in filing, grinding, or polishing the area to be tested. Any grinding should be done wet or with very frequent dippings of the specimen in cold water. It also follows that the smaller the load the more one obtains the hardness of the interior of the mass tested. When deciding what load to use for a particular specimen one should be first guided by the thickness of the material, and then use the highest load available, consistent with this thickness and with the hardness of the material —the minimum thickness for satisfactory testing according to the present B.S.S. is

$$h = \frac{10P}{\sqrt{DH}}$$

where H is the hardness of material. If, however, it is desired to measure the hardness of the surface layers one should use the lowest load available, the ball used being such that $\frac{P}{D^2}$ is maintained at the required value for the class of material tested.

The use of a low and a high load test is frequently very useful to indicate the uniformity of hardness across the section and to detect the presence of hard or soft skins. Soft skins are frequently recognisable in any case by the appearance of a very well defined ridge at the edge of the impression.

When testing hard steels the balls themselves may be deformed and erroneous results produced in consequence. It is not advisable to use steel balls in materials of hardness number greater than about 550 Brinell number. A diamond indentor is to be preferred for materials of higher hardness than this, firstly because the diamond indentors are not deformed as are the steel balls and secondly, because the resulting impressions are more easily read. Spherical shape diamond indentors of 1 mm. diameter can be obtained, but the cone or diamond pyramid indentor, particularly the latter, are now more or less in general use. Cone or pyramid indentors have an advantage over the ball indentors in that the impressions are always geometrically similar and therefore the hardness numbers are independent of the load provided the material is uniform. The rules for the use of diamond indentors of the pyramid type as regards thickness and width of specimen are the same as for ball indentors. The minimum thickness for test is given by

$$t = \frac{0.882}{\sqrt{H}} \text{ in. for 120 kg. load}$$

$$t = \frac{0.441}{\sqrt{H}} \text{ in. for 30 kg. load}$$

$$t = \frac{0.254}{\sqrt{H}} \text{ in. for 10 kg. load}$$

For other loads the minimum thickness is in proportion to the square root of the load.

Other Forms of Static Tests.

The Rockwell test, of which the Avery machine illustrated in Fig. 12 is a type, employs a micrometer dial depth gauge to measure the depth of the impression. Either a $\frac{1}{2}$ in. ball indenter may be use with a 100 kg. load or a diamond cone shaped indentor with a rounded tip with a total load of 150 kg. In each case a minor load of 10 kg. is first applied, the pointer of the scale set to a standard mark and then the major load is put on slowly and after a time

taken off again. The pointer of the dial gauge now points to a figure which is related to the difference of depth of the impression before and after the application of the major load. No calculation, however, is necessary as the dial is marked directly in Rockwell hardness numerals. A certain amount of care is required in carrying out the test, e.g. the underneath surface of the piece must be clean and free from dust and must be well supported. Any movement of the piece during test gives erroneous results. The first impression is usually incorrect due to bedding of the specimen on its table and

Fig. 12.—Avery Hardness Tester.

at least two concordant impressions should be obtained before the figures are adopted. The apparatus is useful for repetition work on certain simple shaped articles, but standardisation of the test is difficult and frequently different machines have been found to give results not in concordance with each other. This makes the question of correlation with the Brinell hardness test very difficult and various published curves for this correlation differ widely.

The Shore Monotron shown in Fig. 13 might be described as an idealised form of test since its object is to produce the same impression in all materials. The load required to produce this impression is then a measure of the hardness of the specimen. It is clear that the elastic deformation of the instrument during the test will affect the results unless it is compensated for in some way an the designers of the instrument state that this object has been

achieved. The author's experience of this machine, however, was not a happy one—he could not obtain concordant and reliable results with the instrument. It will be seen that the instrument has two dials, one which registered the depth of the impression, whereby an impression of pre-determined depth may be obtained and the second which registers the load to produce this deformation. It will be appreciated that this instrument differs from the Brinell test in that the deformation produced by the indentor includes the elastic as well as the plastic deformation.

The Herbert Pendulum, Fig. 14, is a special form of hardness tester in which use is made of the alteration of the time of swing

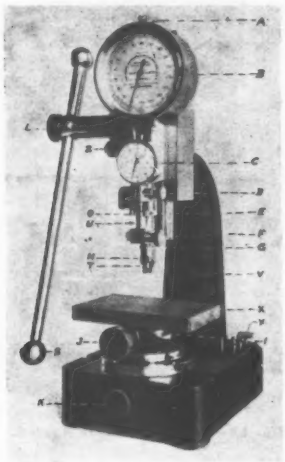


Fig. 13.—The Monotron Hardness Indicator.

of the pendulum by change of the centre of oscillation when the spherical shaped indentor which is the point of support of the pendulum, moves in the groove made by itself. The instrument is apparently one of academic or research interest and few of them, if any, are in use in the works.

Impact Hardness Tests.

The Shore sclerescope measures the hardness of a specimen by the height of rebound of a diamond pointed hammer dropped from a standard height on to the surface to be tested. For soft specimens a magnifier hammer of steel is also occasionally employed. The work

of deformation in making the small impression absorbs some of the energy of fall, so that the softer the material the lower is the height of rebound.

Care must be exercised in using the instrument—it must be kept perfectly vertical and still during the test and the glass tube must be kept clean and free from grease or dirt. The tested surface must be perfectly horizontal and must be smoothly polished to get the

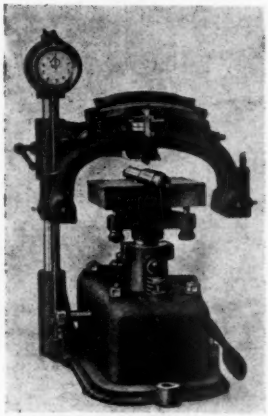


Fig. 14.—The Herbert Pendulum Hardness Tester.

best results. A rough ground surface may give two or three points lower figures than the same surface polished. There are two forms of the instrument, the ordinary type illustrated in Fig. 15 and the recorder type illustrated in Fig. 16. In the latter the hammer is very much heavier than in the former but the height of fall is reduced so that the energy of fall is the same in both cases. The two instruments, however, do not always give identical results especially when used in large masses. On account of the different masses of the two hammers, the size of the mass tested has a greater influence when the heavier hammer is used and although the two instruments give identical readings on the small standard check test piece they do not give identical readings on large masses. e.g., a hard steel roll of say 12 in. diameter which with the ordinary instrument has a Shore value of 95 may give a reading on the recording instrument of 105 to 110. Both instruments when used independently are a useful guide to uniformity of products but the

test in the author's opinion is a very unsatisfactory one for specification purposes.

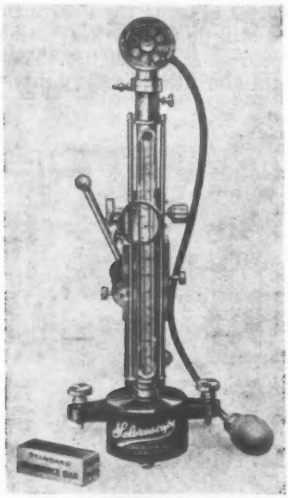


Fig. 15.

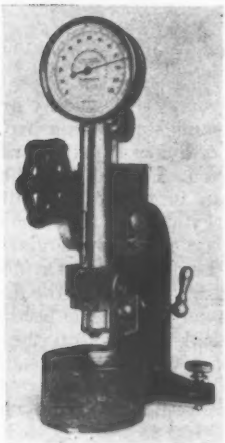
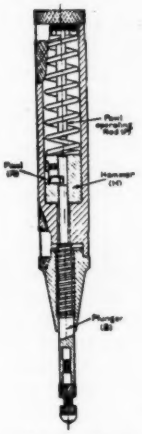


Fig. 16.—The Shore-Brinell Hardness Indicator.

In my experience the sclerescope gives low values when testing thin materials and the author does not recommend the use of this form of test in articles below about $\frac{1}{2}$ in. thick. The best form of test for thin strips is the low load Brinell or diamond test.

The Auto Punch.

This instrument illustrated in Fig. 17, of which there are other similar machines on the market, operates by merely pressing the ball indentor on the surface to be tested. At a certain stage of the



—The Auto-Punch.

Fig. 17.

compression a trip causes a spring load hammer to stike the ball holder with the result that the ball is pressed into the surface of the test material with a constant amount of energy. The diameter of the resulting impression is measured by a microscope and from a calibration curve or chart supplied with the instrument the equivalent Brinell number is obtained.

This tool gives fairly reliable results on large masses but with small masses the hardness numbers tend to be too low even if they are supported on heavy masses of steel.

The Hardness Comparator.

There are several of these on the market all working on the same principle. A hard steel ball usually 10 mm. diameter is placed between the surface to be tested and a standard test bar which is then given

a blow with a hammer. From the size of the two indentations the maximum load of the blow and hence the Brinell hardness of the tested surface can be ascertained. Usually a chart is provided from which the hardness is read off directly from the value of the two impressions. From the nature of the test and from the fact that a variable load is employed, it is clear that this form of test is not very accurate, but in those cases where the job is too large to take it to a small machine and when absolute accuracy is not required the test is a very useful one.

In conclusion the author wishes to acknowledge his thanks to the directors of Thos. Firth & John Brown, Ltd., and in particular to Dr. W. H. Hatfield, F.R.S., Director of Research, for their permission to publish this paper.

Discussion.

MR. FIDLER (Chairman): I would like Mr. Woolman to have gone into the use of machines like the Herbert Pendulum Tester. We who are interested in the machinability of the steels realise that the Brinell test may give you a false idea of the tensile strength of any material with work-hardening properties, and I believe that the Herbert Pendulum Tester does give you some indication of the work-hardening properties of the steel. Or, if you take one of the stainless steels, the same thing seems to me to apply there, so that, for getting some indication of the machinability the Brinell test appears to give entirely the wrong impression. I would like Mr. Woolman to give us a little more information about getting some definite information as to work-hardening qualities of the steel.

MR. WOOLMAN: With regard to Mr. Fidler's remarks, the method by which the Herbert Pendulum is used to determine work-hardening capacity is as follows: the impression when it is first made reaches a certain depth and registers a certain hardness value, then the instrument is rolled backwards and forwards a number of times, so work-hardening the surface. A repeat test with the instrument now gives the hardness of the work-hardened surface, and thereby some conception of the work-hardening capacity is obtained. A similar result may be obtained by carrying out a 1 mm. 30 kg. load Brinell test at the bottom of an impression made by a 10mm. ball under a load of 3,000 kg. I hadn't time to say very much about the tensile-Brinell ratio, but for material of the same type the ratio is reasonably constant, e.g., for ordinary steels the tensile-Brinell ratio is .21 to .23. When you come on to the other type of materials the ratio may be quite different, but for the majority of ordinary steels the Brinell hardness is a fair guide to the tensile strength.

CHAIRMAN: You will have variations in the work-hardening qualities of the steel, and then you have the different ratio?

MR. WOOLMAN: Yes, it is true that materials with different work-hardening capacity have different values for their tensile-Brinell ratio.

MR. STANFIELD: It might be desirable to point out the difference between what is commonly known as toughness and what is called work-hardening capacity. Both have an influence on machin-

ability, but the work-hardening capacity is only one item that goes towards the property of freedom in machining. It is possible to get two steels that have identical Brinell hardness, as determined by the indentation test, and which have very little difference in the ductility as shown by tensile test, and yet those two steels will machine very substantially differently. In one case the tool will stand up for a long time and the other will not stand up at all. The difference is not hardness, and it is scarcely the difference in work-hardening capacity—it is essentially a difference in toughness. I remember on one occasion going to see a certain firm who were having considerable trouble with machinability of steel, and I was very puzzled until I got there as to what was the complaint.

It appeared that they had, for a certain order they had received, bars completely complying with specification, but compared with similar material that they had had previously of the same type, having the same tenslie test values, the tools were only able on the second supply to do about half the amount of work. After discussing the job with them, I quickly came to the conclusion that the complaint in regard to the second steel was that it was not inferior, but that it was too good for their purpose. It had too much toughness. For many jobs you want tensile strength and toughness, the maximum combination of both, but when it comes to machinability, toughness is rather against the operation. The solution of this matter was quite simple—the second batch of steel (which was, by the way, electric steel) was returned and replaced by a cheaper grade of the same type of steel, and everyone was happy.

This question of work-hardness must be really observed by definite measurements in order to be appreciated. During machining, the cutting that is coming off is very deformed, and the greater the amount of deformation the material will stand the harder will be the turning when it is finished. But it is not only a question of how much the material will deform, it is also how much it will harden up from that deformation, and the simplest way of comparing materials with regard to the hardening properties is to have samples cold drawn or cold rolled by a definite amount, and then you can actually compare the curves after the cold rolling, for similar amounts of deformation.

The work-hardening curves of different materials are very interesting, and Mr. Fidler has mentioned the difficulty of handling 12% manganese steel. It so happens that manganese steel is a material that has a very steep curve. The amount of deformation of the turnings from manganese steel is very high, and if you compare the slope of the work-hardening curve with a corresponding curve for ordinary mild steel, the slope is something like four times as

much, and that is a very serious factor in determining machinability. It is clear that there are many factors, all of which have a very substantial effect on machining.

MR. WOOLMAN: I quite agree with all Mr. Stanfield has said as regards machinability, and I intended to make a few remarks about it in my lecture, but in my previous remarks I thought I had emphasised that the Herbert tester does not give any information that could not be obtained by other methods of hardness testing.

MR. GILFILLAN: Might I say that all we want is one machine which will give the reading on the dial, showing the tonnage of the material we have to use. Again, there are many jobs one cannot Brinell. You can take a test piece to any of these machines, but you cannot take the machine to the job. To quote an illustration, some three or four years ago we were manufacturing a lot of case-hardening wheels—3 ft. diameter × about 7 ft. long, and we put two big blocks on a solid table. They showed sclerescope reading of about 72. We said: "Surely everybody will be satisfied with that," but when we took away the blocks we got a reading of 75. Surely there is something wrong with this method of testing, and with this hardening test. The customers came along and rejected it for being 3 tons down. I think there is a great deal to be learned about giving a standardised test for all jobs. Another thing in Brinell testing is, that we cannot get an accurate reading from a circular job. In a Brinell test you have to make allowances. Take the case of a circular ring—you take one reading from the inside and one from the outside, and you have two different readings. It is quite alright on flat surfaces, made resting on tables, but I think that rigidity comes in greatly in the test we have to-day.

MR. WOOLMAN: It is true that with the sclerescope, incorrect results are frequently obtained, and one can only feel sure of the results if the job is really well and truly supported. If there is any "give" in the job—if it is lacking in rigidity, the results obtained are incorrect. The best form of test, to my mind, is the indentation test. You get much more consistent results with that form of test than in any other which I have described, using the diamond indentor, for hard materials, and the ball indentor for softer materials, and the results are not greatly affected by the manner in which the job is supported. As regards reading the tonnage on the dial, well, if you want that test, you can get it if you read your maximum tensile strength on the dial of an Avery tensile testing machine, but one approaches this ideal with the Brinell test—that is, if you interpret it intelligently. If it is an ordinary steel, having obtained its Brinell number, the tensile strength is obtained by use of the Brinell—tensile ratio and it is unnecessary for you to calculate

this, the calculation has been done for you in tables drawn up for the purpose, I think that is not so far removed from what Mr. Gilfillan wants.

With regard to his remarks, that you cannot always take a job to the machine, I did indicate the forms of test which one could use if that were not possible. The Rudge Whitworth auto punch was one and the comparator another, which, although not as accurate as the Brinell and other similar tests, did have an accuracy of the order of 5% which was sufficient for most purposes. These are the instruments which we use.

MR. GILFILLAN : I'm afraid that, on the average test, you do not come to within 5%. Suppose that you fix the diamond test as 100%, and take a comparator test in comparison with the actual job, you are not going to get the same results.

MR. WOOLMAN : If the job is carefully carried out, then the result is within 5%.

MR. GILFILLAN : Within 5% ? I am afraid you couldn't impress the inspector with that. When it is all worked out, you are still in the hands of the boy who takes the reading.

MR. WOOLMAN : I was very careful to say that if the test were *carefully* carried out.

CHAIRMAN : Is there any member of a testing department who can give us an idea of how carefully these tests are carried out ?

MR. DUNDON : If you are taking a tensile test off a material you are taking it inside the material. If you are taking a hardness test, you are taking it on the surface, and therefore the comparative test between the tensile and surface hardening is very unreliable. One often gets misled.

MR. WOOLMAN : I quite agree, the hardness test is definitely a surface test, but provided the material is uniform, there is a reasonable relationship between the hardness and tensile test. I tried to indicate one method of finding out whether the material is uniform. If the results from the low and high load Brinell tests differ, the material is not uniform, and therefore you must grind away the surface until you get results which agree, if you wish to obtain the time hardness of the interior. If you want to know the tensile strength of a material by a Brinell test, use a 3,000 kg. test, and you are not usually very far wrong, unless the surface of the material is either very severely decarbonised or case-hardened.

MR. SHERWOOD : A few years ago, we had some testing done by the Sheffield Testing Works, and there was an error of 1 or 2%. I think it is most important, if you want accurate results, you must have accurate inspection and preparation of specimens.

MR. GILFILLAN : So, it is only up to the boys who do the reading !

MR. WOOLMAN : I cannot emphasise too much the need for care in reading, in Brinell hardness tests.

Mr. Woolman then described the machine used by the Sheffield Testing Works, remarking that one has frequently to rely on the makers of the machines as to the accuracy of the load produced by the machine. Where standard test pieces are supplied these should be frequently used to check the accuracy of the machine.

THE CHAIRMAN mentioned the Vickers hardness tester as a " falling weight " machine.

MR. WOOLMAN then described the Vickers hardness tester.

MR. BATTY : Do you expect to get reliable results from a test bar cast at the same time as a cast iron casting ?

MR. WOOLMAN : In the case of cast iron, the Brinell test has no relation whatever to the tensile test. The actual hardness and tensile strength of the material of cast iron depends upon the size of casting and one cannot be sure that the results of tests on a small bar will be the same as those on a large mass of cast iron from the same cast.

CHAIRMAN : Were you thinking of cast iron ?

MR. BATTY : Well—an experience we had some time ago was this : The test bar was eventually sent sway for testing (a specific tensile test being required) and did not give the test called for by the specification. There was consideration given to condemning the casting, however, as there was not the means of testing in the bulk. The casting was eventually broken up and a test piece was cut out of the cast and sent away for testing, and actually produced a 50% higher tensile than the large casting.

MR. STACEY : We Brinell the rims with a comparator test, and do not always get the same readings that we should expect to get for the tensile strength of the material as compared with a suitable comparator bar. We were wondering if the lack of rigidity in the rim had anything to do with this ; if we take a large hollow forging, and strike this with a hammer—naturally we get a certain amount of spring. However, we do not get the readings we expect always on the comparator : is it due to spring or lack of mass ?

MR. WOOLMAN : Lack of rigidity itself should not affect the results obtained with a comparator, but it has the tendency of reducing the severity of the blow and the resulting impressions tend to be too small to give accurate results. Best results are obtained when the size of the impressions are similar to those which would be obtained with a 3,000 kg. machine.

MR. STANFIELD: May I suggest that, however much this rim springs will not affect the Brinell figures between the camber and the rim, because it does not affect mutual pressure at the time; if there was a discrepancy, it is more likely to be found in the lack of uniformity of the rim.

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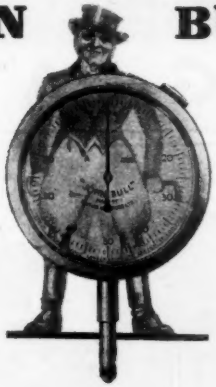

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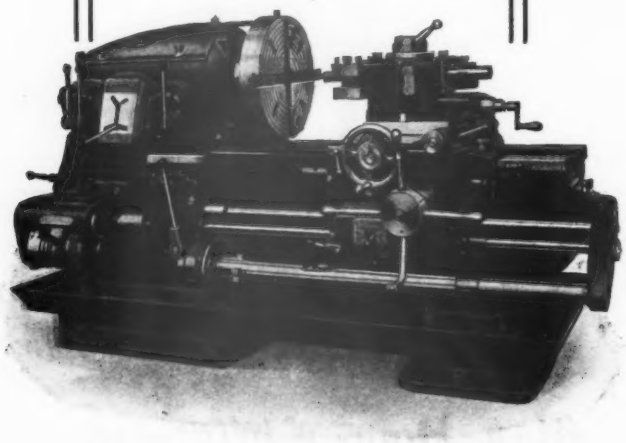

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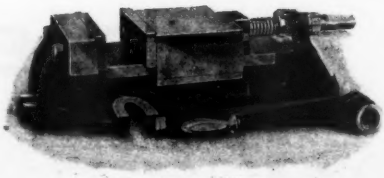

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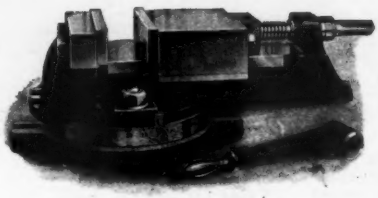

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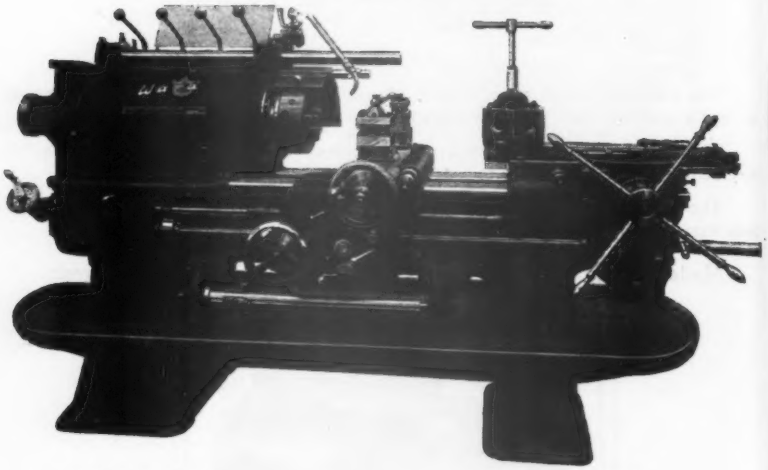

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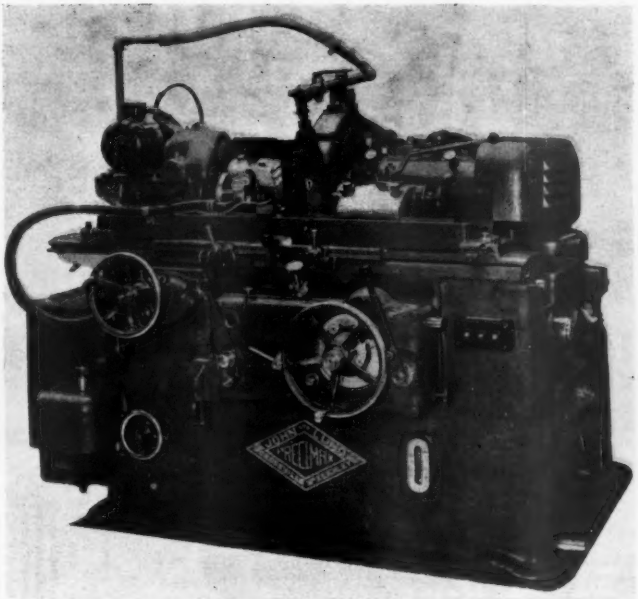

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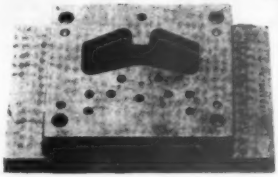

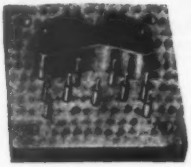

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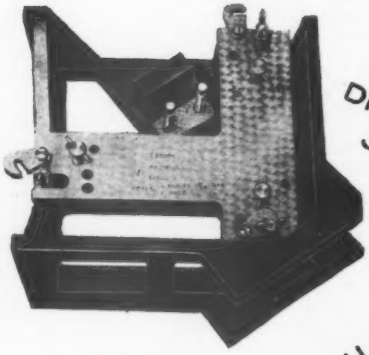

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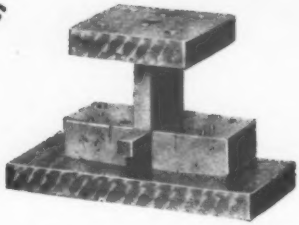

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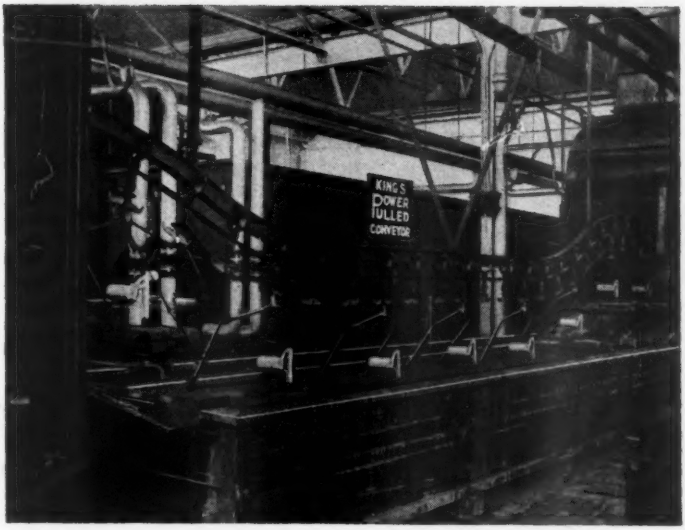

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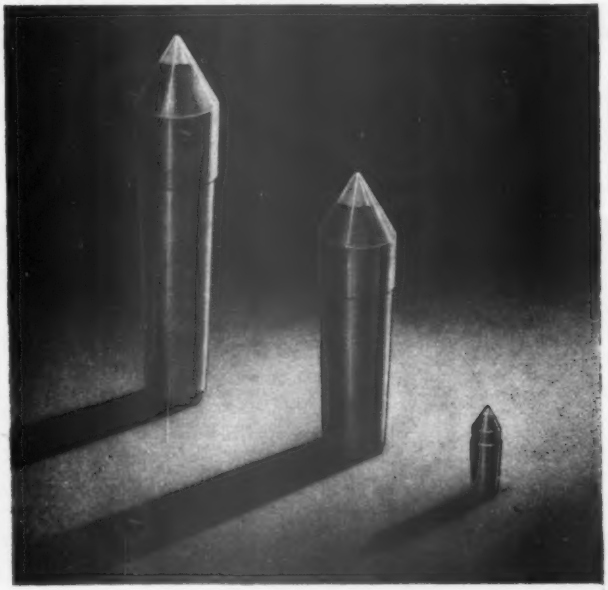

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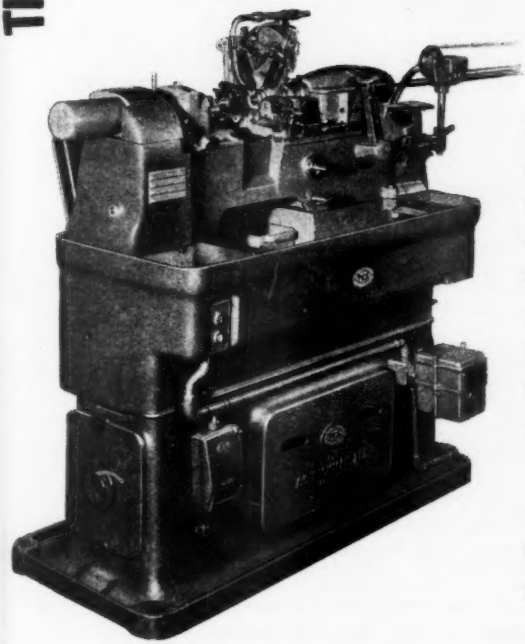

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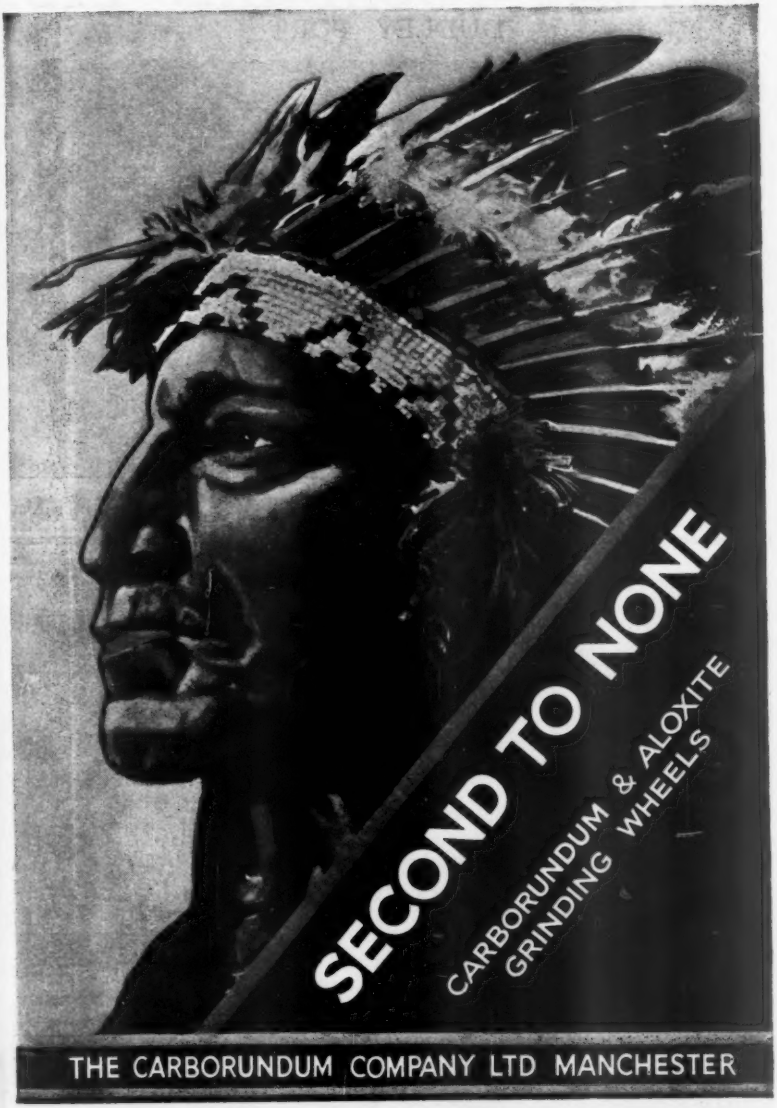
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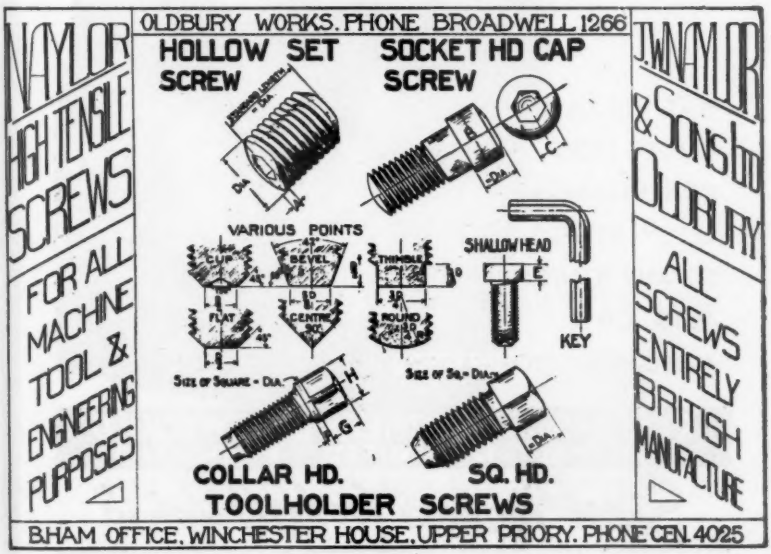

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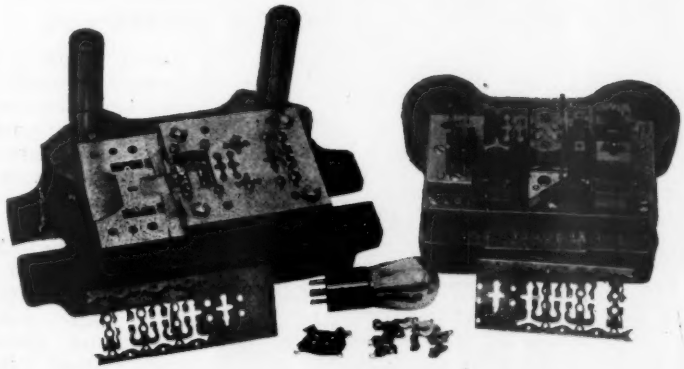

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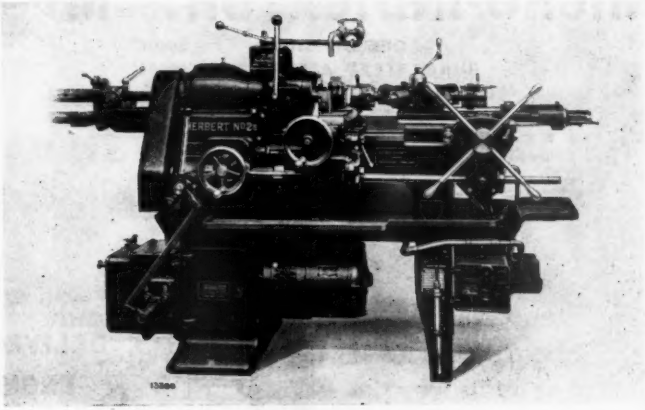

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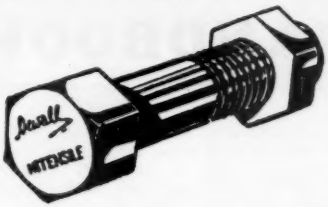

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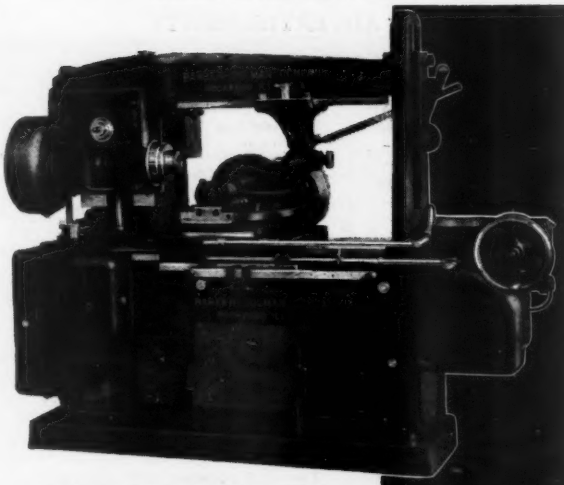

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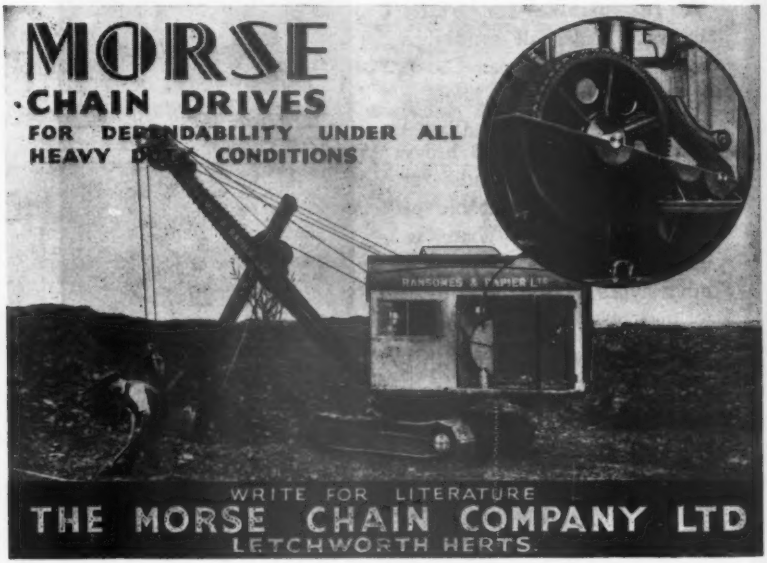

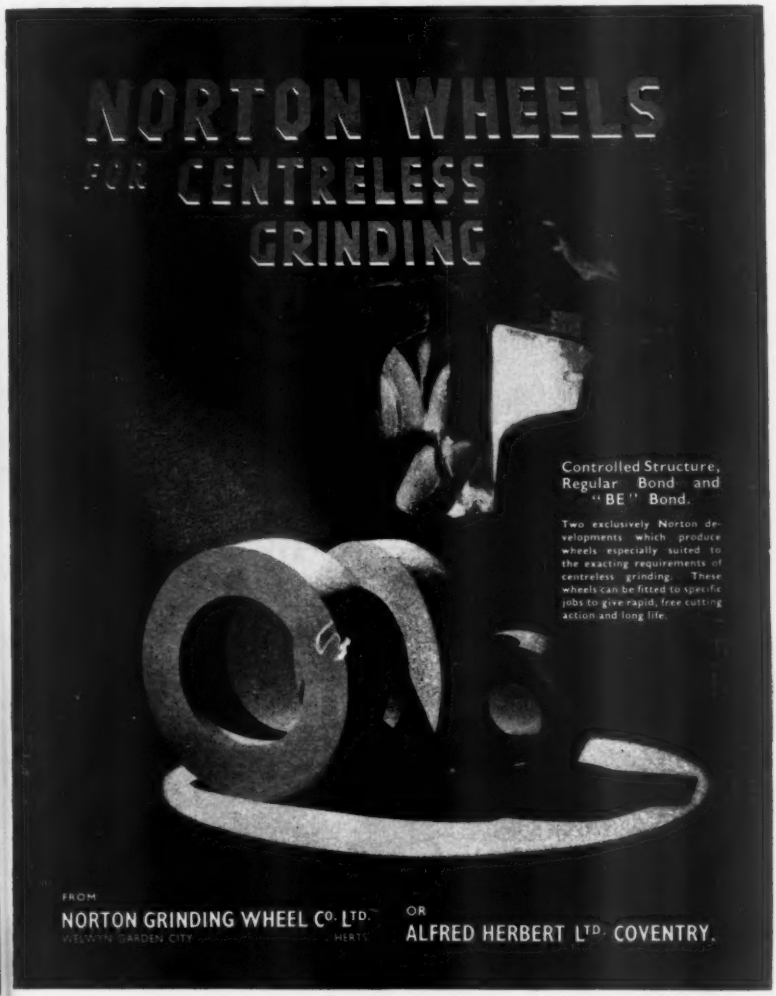
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